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ASARCO

Linda Jacobson (3 Copies)
RCRA Project Manager
US EPA Region VIII
8ENF-T
1595 Wynkoop Street
Denver, Colorado 80202-1129

June 29, 2009

SENT BY ELECTRONIC MAIL AND
CERTIFIED MAIL RETURN RECEIPT REQUESTED

Re: Baseline Ecological Risk Assessment (BERA) Work Plan, Asarco East Helena Site

Dear Ms. Jacobson:

Pursuant to your June 9, 2009 letter, Asarco herewith submits the Baseline Ecological Risk Assessment (BERA) Work Plan (June 2009) for the Asarco East Helena Site. A copy of the Work Plan is simultaneously being submitted in the enclosed compact diskettes. The Work Plan, compact diskettes, and the certification signed by an officer of ASARCO LLC (Asarco) are attached to this letter.

Be advised that, due to the extent and specifics that EPA has requested in the BERA Work Plan and the effort necessary to review and screen the historical site data, submittal of the field Sampling and Analysis Plan (FSAP), which is an appendix to the BERA Work Plan, will be delayed. With the upcoming holiday, we expect the FSAP to be forthcoming no later than July 9, 2009. We understand that EPA has committed to expediting the review and approval of the Work Plan in hopes of conducting some level of fieldwork this season.

The Settlement Agreement requires advanced approval of activities and expenditures to be considered Response Costs. Now that the BERA Work Plan has been assembled, Asarco will develop an estimate of BERA Work Plan proposed expenditures, which will be provided to EPA in the next few days. Asarco seeks written approval from EPA that preparation and implementation of the BERA Work Plan qualifies as Response Costs.

Please immediately notify me if have any questions on the Work Plan.

Sincerely,

Jon Nickel

Jon Nickel

Enclosures

CC: Denise Kirkpartrick (MDEQ)
Karen Nelson (FWS)

CERTIFICATION
PURSUANT TO U.S. v ASARCO INCORPORATED
(CV-98-3-H-CCL, USDC, D. MONTANA)

I certify under penalty of law that this document, Baseline Ecological Risk Assessment Work Plan (June 2009) and all attachment, were prepared under my direct supervision in accordance with a system designed to assure that qualified personnel gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and completes. I am aware that there are significant penalties for submitting false information, including the possibility of fine or imprisonment for knowing violations.

Signature [signature]
Name: Thomas L. Aldrich
Title: Vice President Environmental Affairs
Date: June 29, 2009

Exponent®

Baseline Ecological Risk Assessment Work Plan (June 2009): Asarco East Helena Facility, East Helena, Montana

Rec'd 7/2/09

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Baseline Ecological Risk Assessment Work Plan (June 2009): Asarco East Helena Facility, East Helena, Montana

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Ecological Risk Assessment Work Plan (June 2009): Asarco East Helena Facility, East Helena, Montana

Prepared for

ASARCO LLC
East Helena, Montana 59635

Prepared by

Exponent
Boulder, CO

June 2009

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Acronyms and Abbreviations

ALA-D	delta-amino levulinic acid dehydratase
AVS	acid-volatile sulfide
BERA	baseline ecological risk assessment
CAMU	Corrective Actions Management Unit
CCME	Canadian Council of Ministers of the Environment
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980
COC	chemical of concern
CoPC	chemical of potential concern
CSM	conceptual site model
EcoSSL	ecological soil screening level (EPA)
EPA	U.S. Environmental Protection Agency
EPC	exposure-point concentration
ERA	ecological risk assessment
FS	feasibility study
FSAP	field sampling and analysis plan
FWS	U.S. Fish and Wildlife Service
HQ	Hazard Quotient
ISQG	interim sediment quality guidelines (Canada)
LOAEL	lowest-observed-adverse-effect level
MDEQ	Montana Department of Environmental Quality
MFWP	Montana Department of Fish, Wildlife and Parks
MNHP	Montana Natural Heritage Program
NOAEL	no-observed-adverse-effect level
NRWQC	National Recommended Water Quality Criteria
NSTP	National Status and Trends Program
NWI	National Wetland Inventory
ORNL	Oak Ridge National Laboratory
PEC	probable effects concentration
PEL	probably effect level
QA	quality assurance
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
RI	remedial investigation
SEM	simultaneously extracted metals
SOP	standard operating procedure
SQG	sediment quality goal
SSTT	spiked-sediment toxicity test
TEC	threshold effect concentrations
TEL	threshold effect level
TMDL	total maximum daily load
TOC	total organic carbon

TRV	toxicity reference value
UCL	upper confidence limit
ZPP	zinc protoporphyrin

1 Introduction

The purpose of the East Helena Smelter baseline ecological risk assessment (BERA) is to estimate the likelihood and magnitude of unacceptable risks to ecological receptors posed by current or future exposure to metals in soil, water, sediments, and biota at the site and in areas immediately surrounding the site. Elevated metals concentrations have been identified in surface water, sediment, surface soil, and groundwater at the site, primarily as a result of deposition from historical stack and fugitive emissions, slag, and process water. The BERA has been designed to provide adequate information to support risk management decisions and determine whether corrective measures are needed to protect ecological resources at the site. This work plan identifies and describes the tasks necessary to conduct the BERA.

The risk assessment is being conducted as part of the Phase II Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI), and is designed to be conducted in a phased approach. Phase I of the BERA includes the 2009 field sampling program and completion of the draft BERA. Depending on the outcome of the Phase I assessment, Phase II sampling for the BERA may be conducted in 2010, to gather more information for those exposure pathways and ecological receptors with sufficient data gaps to prevent firm conclusions on potential risks.

The U.S. Environmental Protection Agency (EPA) identified data needs in letters (from Linda Jacobson to Jon Nickel on April 22, 2009, and May 29, 2009) and in a conference call on April 30, 2009. In response to this input, Exponent developed responses to comments on the Technical Memorandum, as well as this BERA work plan and the field sampling and analysis plan (FSAP; Appendix A), to guide Phase I data collection in the summer 2009 field season.

This BERA work plan was prepared in accordance with guidance set forth in EPA's (1997) *Ecological Risk Guidance for Superfund*, and includes:

- A general overview and background of the site, including the physical setting, ecology, and current and future uses
- A summary and analysis of previous site investigations

- A preliminary conceptual site model, including identification of the potential exposure pathways selected for analysis, the assessment endpoints and risk questions, and the selected measures of effect
- The identification of Phase I site investigations that will be conducted to support the BERA
- An outline of Phase II activities that may be necessary depending on the outcome of the Phase I assessment.

A detailed description of the Phase I sampling activities is presented in the FSAP, along with the anticipated schedule of these activities (Appendix A).

1.1 Document Organization

The sections of this work plan document are:

- Section 1, Introduction
- Section 2, Summary of Previous Investigations
- Section 3, Identification of Chemicals of Potential Concern
- Section 4, Preliminary Conceptual Site Model
- Section 5, Phase I Ecological Site Investigations (2009)
- Section 6, Baseline Ecological Risk Assessment
- Section 7, Phase II Ecological Studies (2010)
- Section 8, References
- Appendix A, Field Sampling and Analysis Plan (FSAP)
- Appendix B, Application for Scientific Collector's Permit.

1.2 Site Overview

The Asarco East Helena facility was a former lead smelter, and is situated on approximately 142 acres near East Helena, Lewis and Clark County, Montana. Facility operations were halted in April 2001. Currently, the facility site is undergoing decommissioning.

The site is bounded to the south by Upper Lake and Lower Lake, to the east and northeast by Prickly Pear Creek, and to the north by the City of East Helena and American Chemet (refer to Figure 1). Lands surrounding the facility to the east and west are agricultural and rangeland. The site itself offers only limited habitat, except for the onsite water bodies—Lower Lake and Upper Lake—and the marshes associated with Upper Lake. Prickly Pear Creek, which runs along the eastern boundary of the site, also provides aquatic and riparian habitat. The interior portions of the site are covered with buildings, paved with concrete, or otherwise disturbed. Onsite, there are areas that are currently undergoing demolition, and a large slag pile is situated in the northeast quadrant of the site. The intake for Wilson Ditch is at Upper Lake, and the ditch flows adjacent to the facility site. Future site use for the facility has not been determined. However, several future land-use scenarios are being considered, including:

- Existing conditions. The site remains in its present state. No significant actions that result in a change of future land use are being implemented.
- Industrial use. A portion or all of the facility is used for industrial purposes. This might include reprocessing of slag or use of the area for warehouse or other industrial uses.
- Agricultural use. This scenario assumes that the facility would be capped and revegetated, with institutional controls that would ensure the integrity of the cap. This may limit future agricultural use to grazing of livestock.
- Recreational use. This scenario assumes that the facility would be capped and revegetated, an institutional controls would be put in place to ensure the integrity of the cap. This land-use scenario assumes that the facility area is

used occasionally for outdoor recreational purposes such as hunting, fishing, hiking, bird watching, etc.

2 Summary of Previous Investigations

Previous site characterization investigations have shown that site surface and subsurface soils contain elevated metals, of which arsenic, cadmium, copper, lead, and zinc show the highest concentrations (Asarco Consulting Inc. 2005). Limited data on aquatic habitat and exposure levels from onsite water bodies were collected, leading to the supplemental ecological field investigation that was performed in 2003 as part of the Supplemental ERA (U.S. EPA 2005b). In addition to the Supplemental ERA, a number of investigations have been conducted at the site that are pertinent to ecological assessment. These are summarized briefly in the sections below. Table 1 presents a summary of the types of data collected and the locations where these data were collected.

2.1 Remedial Investigation of Soils, Vegetation, and Livestock (1987)

The Remedial Investigation of Soils, Vegetation, and Livestock (RI; CH2MHill 1987a) included the sampling and analysis of soils, plant tissues, and cattle resources from the site and throughout the Helena Valley. Along with the RI, two related reports, which were based on literature reviews, are summarized here as well:

- Assessment of the toxicity of arsenic, cadmium, lead, and zinc in soil, plants, and livestock in the Helena Valley of Montana (CH2MHill 1987b)
- Assessment of the toxicity of copper, mercury, selenium, silver, and thallium in soil and plants in the Helena Valley of Montana (CH2MHill 1987c).

The purpose of the 1987 RI of soils, vegetation, and livestock was to characterize the nature and extent of contamination in soil, vegetation, and cattle in the Helena Valley and to identify remedial action alternatives. Although dated, the 1987 RI also contains an extensive site description, a brief summary of site operations, maps and aerial photographs of the site and surrounding areas, local wind data, maps depicting distribution of various metals, human population data, wildlife and endangered species information, and an analysis of soil properties.

No endangered species were reported to occupy the Helena Valley at the time of this report, although it is stated that migratory bald eagles or peregrine falcons could possibly enter and make use of habitat in the Helena Valley. The RI Appendices include detailed sampling and analysis method descriptions, scientific names of plants sampled, soil descriptions and physical data, descriptions of the ranches and cattle sampled, statistical analysis results, and raw data for the soil, vegetation, and cattle investigations.

2.1.1 Soil Investigation

The objectives of the 1987 RI soil investigation were to:

- Determine whether soil metals were elevated due to site contamination
- Map the spatial distribution of soil metals relative to the smelter
- Evaluate the horizontal and vertical distribution of metals in soil, and investigate soil properties that influence this distribution.

A total of 157 soil sample locations were sampled at a depth of 0–4 inches. A subset of 47 locations were sampled to 30 inches depth, at intervals of 4–8, 8–15, and 15–30 inches. A reference site located 27 miles southeast of the smelter was sampled to represent local background. Several metals occurred at concentrations exceeding background: silver, arsenic, cadmium, copper, mercury, manganese, lead, selenium, tin, thallium, and zinc. Exceedances ranged from 1.3 to 27 times greater than background. Soil metal concentrations tended to be elevated east of the smelter based on kriging analysis, which is consistent with the prevailing wind direction in the Helena Valley, from west to east. The highest metals concentrations occurred in the 0- to 4-inch layer, although some metals existed as deep as 30 inches.

2.1.2 Vegetation Investigation

The objectives of the 1987 RI vegetation investigation were to:

- Determine whether plants and grain heads in Helena Valley contain elevated metals
- Describe metal concentrations in plants in terms of phytotoxicity benchmarks and allowable concentrations in forage for livestock consumption
- Describe areal distribution of metals in plants
- Investigate the relationship between metals concentrations in soils and in plants.

The vegetation investigation compared plants and grains grown in the Helena Valley to the reference location 27 miles southeast of the smelter. Samples of forage, range grass, barley, and wheat were collected from 58 sites corresponding to soil sample locations. Alfalfa, needle-and-thread grass, winter wheat, and barley all had elevated metals concentrations relative to background. Significant correlations were found between soil concentrations and total plant and grain-head metal concentrations.

2.1.3 Livestock Investigation

The objectives of the 1987 RI livestock investigation were to:

- Determine whether cattle are exposed to site contaminants
- Investigate the level of exposure in terms of the spatial distribution of site-related contaminants
- Investigate the relationship between cattle exposure concentrations and soil and vegetation concentrations
- Describe the concentrations of metals in cattle tissue.

The livestock investigation looked at cattle whole blood, blood serum, and hair and compared metals concentrations in Helena Valley cattle herds to cattle herds from the reference location. Arsenic, cadmium, lead, and zinc were elevated in cattle whole blood compared to the reference location. Significant relationships existed between cattle-blood lead concentrations and surface-soil lead concentrations, although this relationship was not significant for arsenic, cadmium, or zinc. Arsenic and lead concentrations in cattle blood were greatest closer to the smelter and decreased with distance. This relationship was not significant for cadmium or zinc.
A relationship was also noted between cattle-blood lead and vegetation concentrations.

2.1.4 Toxicity of Arsenic, Cadmium, Lead, and Zinc in Soil, Plants, and Livestock (1987)

The assessment of the toxicity of arsenic, cadmium, lead, and zinc in soil, plants, and livestock in the Helena Valley of Montana was prepared by CH2MHill (1987b) and is the first of two volumes. It presents a literature review that was conducted to assess candidate hazard levels for metals associated with the site and the Helena Valley specifically. Hazard levels were developed to assess risk to plants and livestock from metals found in soil, plants, livestock, and water, and to determine potential impacts to agricultural resources. The literature review did not give greater importance to either field or lab studies and did not consider the synergistic effects of metals. Weight was added to studies that took place in the Helena Valley and/or contained conditions and/or species similar to those present in the Helena Valley.

The report listed background concentrations and toxicity data for each metal in numerous media in a series of tables in the report. Media include livestock, plants, soil, and water. Regulatory criteria from other sources were also considered: land application of sewage sludge, coal overburden suitability for root-zone material, criteria defining hazardous wastes, and criteria for metal contaminants based on land use. The report also contains summaries of the toxicological mechanisms of each metal for both livestock and plants. However, the regulatory and toxicological information are outdated and may not be relevant today.

"Tolerable levels" for plants and livestock were selected on the basis of the maximum concentrations at which no toxicity was noted. Selection of "toxic concentrations" was based on results of individual studies, as well as criteria reported as toxic in the literature. A summary section and/or summary table for selected criteria and concentrations does not exist in this document, and much of the information it contains is likely outdated.

2.1.5 Toxicity of Copper, Mercury, Selenium, Silver, and Thallium in Soil and Plants (1987)

The assessment of the toxicity of copper, mercury, selenium, silver, and thallium in soil and plants in the Helena Valley of Montana, prepared by CH2MHill (1987c), is the second of the two volumes described above and contains similar information for those metals. This volume addresses soil and plants, unlike the first volume, which addresses soil, plants, and livestock.

2.2 Process Pond Remedial Investigation/Feasibility Study (1989)

The Process Pond Remedial Investigation/Feasibility Study (RI/FS) was prepared by Hydrometrics and Hunter/ESE (1989) for Asarco and addresses the first operable unit assigned to an accelerated schedule set by EPA and Asarco. The operable units for the site are listed as:

- Process Fluids (includes Process Ponds and Process Fluids Circuits sub-units)
- Groundwater
- Surface Soils/Surface Water (includes onsite soil, residential East Helena soils, limited Helena Valley Soils, Prickly Pear Creek, Wilson Ditch, Vegetation, Cattle, Fish, and Waterfowl sub-units)
- Slag Pile
- Ore Storage Areas.

The Process Pond operable sub-unit, which along with the Process Circuit sub-unit composes the Process Fluids Operable Unit, consisted of four process ponds: Lower Lake, the former speiss granulating pond and pit, the former acid plant water treatment facility, and former Thornock Lake. The other operable units are covered in the 1990 Comprehensive RI/FS. The

Process Pond investigation included a water-balance investigation of the main process-water circuit for Lower Lake and a physical characterization of each pond. Physical characterization included the sampling of sediment, soil, process water, and process fluids. Information obtained to characterize the four ponds could be useful for considering the fate and transport of contaminants. Available information that could be of use in the BERA includes geological descriptions, some information on contaminant distribution, geochemical descriptions of surface water and sediment, and toxicology data (see description of Endangerment Assessment below). Much of the report, however, deals with remediation issues and is not pertinent to ecological assessment.

The endangerment assessment portion of the Process Pond RI/FS (Section 5.0 of the Process Pond RI/FS) identifies the metals of concern for public health and the environment as arsenic, cadmium, copper, lead, and zinc. A non-site-specific toxicity assessment describing health and environmental hazards of each chemical of concern is given. These assessments include information on criteria and standards, toxicodynamics, and information on effects to aquatic and terrestrial organisms.

Volume II of this document consists of 16 Appendices that contain information such as photographs, chemical data, well boring and geological logs, groundwater data, etc.

2.3 Comprehensive RI/FS (1990)

The Comprehensive RI/FS (Hydrometrics, Inc. 1990) covers the following operable units of the site:

- Groundwater
- Surface Soils/Surface Water (includes onsite soil, residential East Helena soils, limited Helena Valley Soils, Prickly Pear Creek, Wilson Ditch, Vegetation, Cattle, Fish, and Waterfowl sub-units)

- Slag Pile
- Ore Storage Areas.

The Process Fluids operable unit was evaluated in the 1989 Process Pond RI/FS. The Surface Soils/Surface Water investigation is summarized below. The other operable units are not relevant to ecological investigations and therefore are not summarized here.

The Surface Soils/Surface Water investigation addressed:

- Soil samples from the site and from other locations in East Helena
- Water samples from Prickly Pear Creek, Upper Lake, and Wilson Ditch
- Groundwater/surface-water interactions at Prickly Pear Creek
- Surface-water drainage mapping and double-ring infiltrometer test
- Vegetable samples from residential gardens and grain samples from Helena Valley
- Helena Valley cattle
- Fish in Prickly Pear Creek and Lake Helena
- Waterfowl/sediment comparison literature review
- A biological inventory for Upper Lake.

The Surface Soils investigation was conducted to determine the nature and extent of metals in surface soils at the site and in the East Helena area to determine wind dispersion of soil particulates and to determine the amount of contaminated surface soil that could enter Prickly Pear Creek during a storm event.

The Surface Water investigation was conducted to measure flow/seepage, surface-water quality, and metals in sediment. The investigation also measured surface-water/groundwater interrelationships, an evaluation of surface-water uses, and an evaluation of flux of contaminated soils entering Prickly Pear Creek during runoff events. Surface water was sampled from Prickly Pear Creek, Upper Lake, and irrigation ditches. Sediment was sampled from Prickly Pear Creek, Wilson Ditch, and Upper Lake. Surface-water/groundwater interrelationships were investigated via continuous water-level recorders installed in monitoring wells located at Prickly Pear Creek, in shallow aquifer, in intermediate aquifer, and in East Helena north of Highway 12. Surface-water drainage on the site, in catchment basins, and offsite runoff areas were assessed to determine frequency of water retention and fate of runoff.

The Vegetation Investigation was conducted to determine commercial and residential production and consumption patterns of food crops and to determine metal concentrations in plant tissue.

The Cattle Investigation was conducted to determine production and consumption patterns of locally grown beef and to determine metals concentrations in beef.

Fish were sampled from Prickly Pear Creek and Lake Helena and analyzed for metals. In Prickly Pear Creek, brook trout and rainbow trout were targeted, but only brown trout were captured. In Lake Helena, carp, brown trout, and rainbow trout were targeted. No carp were captured, but brook trout, brown trout, white sucker, and longnose sucker were sampled.

A literature review was conducted to determine potential exposure pathways for waterfowl. Exposure via surface water and sediment were the media considered. The ultimate goal of the assessment was to determine potential exposure of humans to metals in waterfowl.

A biological inventory of Upper Lake was conducted to map wetlands and inventory wildlife species.

2.4 Metal Residues in Sediment and Biota from Prickly Pear Creek and Lake Helena (1997)

This U.S. Fish and Wildlife Service report, titled "Biological Indices of Lead Exposure in Relation to Heavy Metal Residues in Sediment and Biota from Prickly Pear Creek and Lake

Helena, Montana," investigated metal exposure in benthic invertebrates and fish in Prickly Pear Creek, both upstream and downstream of the site, and in mallard ducks in Lake Helena (downstream of site) and Canyon Ferry Lake (a reference site). The study also measured metals in sediment in Prickly Pear Creek and found no significant difference in concentrations of arsenic, cadmium, copper, lead, or zinc in samples collected upstream and downstream of the site. These metals were elevated in the vicinity and immediately downstream of the site, however.

Whole-body fish and benthic invertebrate samples were collected and analyzed, and concentrations of arsenic, copper, lead, and zinc were found to be significantly higher downstream of the site in stonefly larvae. Significant differences were not observed in miscellaneous benthic invertebrates, rainbow trout, brook trout, and sculpin, although concentrations from animals taken below the site were elevated compared to above the site. (It is important to note that, throughout the report, differences between upstream and downstream data sets that were determined to not be statistically significant are still described as "elevated.")

Blood lead levels in mallard ducks were measured and found to be elevated at both site and reference locations (>0.2 µg/g wet weight, 0.8 µg/g dry weight). Lead in Lake Helena mallard blood was reported to be significantly higher than in reference mallards in Canyon Ferry Lake, yet a significance level of $p = 0.11$ is reported. Typically, a p-value greater than 0.05 is not considered significant.

Blood lead concentrations from rainbow trout and brook trout sampled downstream of the site were higher than those sampled upstream of the site. Blood lead concentrations of mountain sucker were not significantly different upstream and downstream of the site, and blood lead concentrations overall were lower than that observed in trout.

Delta-amino levulinic acid dehydratase (ALA-D) enzyme activity, which is inhibited by lead, and hemoglobin levels in mallard blood were both significantly higher in mallards from Canyon Ferry Lake (reference site) than in Lake Helena (downstream of the site). Zinc protoporphyrin (ZPP) activity, which is another measure of lead impairment, did not differ significantly in mallard blood samples taken from Lake Helena and Canyon Ferry Lake. In rainbow trout, brook trout, and mountain sucker, ALA-D activities were not significantly different in upstream and downstream portions of Prickly Pear Creek. Hemoglobin in mountain sucker was significantly higher in fish sampled downstream of the site. There were no significant differences in hemoglobin for rainbow trout or brook trout. Although trout exhibited higher lead burdens than mountain sucker, ALA-D activity indicated no impairment.

The study concluded that some metals are elevated below the site relative to reference conditions and that this is partially reflected in the biota. Recommendations are made to continue cleanup of the Corbin-Wickes historical mining district to reduce metals input into Prickly Pear Creek and Lake Helena, to monitor aquatic biota to document lead exposure, and to further investigate sediments in Lake Helena and Prickly Pear Creek.

2.5 Supplemental Ecological Risk Assessment (2005)

The Supplemental ERA (U.S. EPA 2005b) was conducted by U.S. EPA Region 8 to address data gaps in the 1987 RI, specifically to gather data on the habitat and contaminant concentrations in the onsite lakes (Lower Lake and Upper Lake), Prickly Pear Creek, and the marsh area, as well as reference sites, including Canyon Ferry Reservoir and Prickly Pear Creek upstream of the site.

Data that were used in the Supplemental ERA included surface water, sediment, sediment porewater, aquatic plants, aquatic invertebrates, and fish. Samples were analyzed for metals, sediment toxicity (*Hyalella azteca*, amphipod), and benthic macroinvertebrate community. The Supplemental ERA addressed exposure to fish, benthic invertebrates, terrestrial plants, terrestrial soil invertebrates, wildlife (birds and mammals), and livestock. The ERA used data collected by EPA in their 2003 field study for surface water, sediment, sediment toxicity, sediment porewater, benthic invertebrate tissue, benthic invertebrate community assemblage, fish tissue, and aquatic plants. EPA also used fish tissue and benthic invertebrate tissue data collected earlier by the U.S. Fish and Wildlife Service (FWS) for their 1997 study titled, "Biological indices of lead exposure in relation to heavy metal residues in sediment and biota from Prickly Pear Creek and Lake Helena, Montana." The Supplemental ERA used data from seven benthic invertebrate tissue samples collected by FWS and three collected by EPA. For fish tissue, the Supplemental ERA used data from fifteen samples collected by FWS and eight samples collected by EPA.

The risk assessment for aquatic receptors incorporated several lines of evidence each and applied a Hazard Quotient (HQ) approach. The lines of evidence considered for aquatic receptors included analysis of metals in surface water, sediment, and sediment porewater, site-specific sediment toxicity testing with benthic invertebrates,[1] evaluation of fish exposure via ingestion of food and incidental ingestion of sediment, and evaluation of body burdens of aquatic organisms.

For aquatic receptors, it was found that the risk of population-level effects to fish and benthic invertebrates was:

- Moderately high for fish and high for benthic invertebrates in Lower Lake
- Minimal to low for fish and low for benthic invertebrates in Upper Lake and the marsh area
- Minimal for fish and minimal to low for benthic invertebrates in Prickly Pear Creek.

For wildlife receptors, the exposure pathways considered were ingestion of metals in surface water, ingestion of metals in soil or sediment, and ingestion of metals taken up in food. Based on studies conducted at an unrelated smelter site in Montana (Anaconda Smelter Site, Deer Lodge County), it was determined that invertivorous song birds would be the primary terrestrial receptor of concern. Waterfowl, piscivorous birds, and piscivorous mammals were also evaluated. Concentrations of metals in surface water, sediment, soil, and some food items were measured, and concentrations of metals in some food items were estimated (e.g., in Prickly Pear Creek, concentrations in aquatic plants were assumed to be equal to those measured in benthic invertebrates).

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1 Sediment toxicity testing was limited to the *Hyalella azteca* 10-day survival and growth test; samples were collected from Lower Lake, Upper Lake/Marsh, and two Canyon Ferry Reservoir reference sites.

Food-chain modeling and an HQ approach were used to characterize wildlife exposure. Estimated risk from ingestion of surface water was below the level of concern at all exposure areas. For food and sediment ingestion pathways, arsenic, cadmium, copper, lead, selenium, and zinc were identified as metals of concern for wildlife receptors. Table 6-8 in the Supplemental Ecological Risk Assessment summarizes the primary drivers of predicted risk in wildlife by receptor type and location. This table has been modified and included in this summary in Table 2.

To characterize risk for terrestrial receptors in offsite upland areas, the supplemental ERA relied heavily on data for soils, small mammals, bird eggs, nestlings, and food items collected at the Anaconda Smelter site in Deer Lodge County, Montana, and did not incorporate site-specific data. At the Anaconda site, the primary receptors of concern were identified as insectivorous passerines for exposure to lead at soil concentrations greater than 650 mg/kg. The spatial distribution of soil lead concentrations above 650 mg/kg at the East Helena site was evaluated, and it was found that elevated lead concentrations extended about 1 mile east of the site, compared to ¼ to ½ mile west of the site. The supplemental ERA concluded that passerine insectivores may be adversely affected in areas close to the East Helena smelter where soil lead concentrations exceed 650 mg/kg, assuming that exposure and toxicity are similar to the Anaconda site.

2.6 Summary of Data Gaps from Previous Investigations

The review of the previous investigations revealed the following data gaps, which the BERA has been designed to address:

- Present-day habitat descriptions, including current observations of species that are present, are not available for the site
- The previous studies did not assess the complete list of 19 metal analytes, or methyl mercury

- In some of the previous studies, including the supplemental ERA, detection limits were inappropriate (i.e., not sufficiently low) to characterize ecological exposure and risk

- The previous investigations did not adequately characterize all the relevant exposure areas for the site (e.g., few samples for certain exposure areas, no bank samples, limited biota tissue data set)

- No sediment toxicity testing was done on Prickly Pear Creek.

3 Identification of Chemicals of Potential Concern

The existing data for chemicals detected in surface water, sediment, and surface soil were screened to identify chemicals of potential concern (CoPCs). This was accomplished by comparing detected chemical concentrations in these media with ecological risk-based screening benchmarks and criteria. Chemicals that are present in surface water and sediment at concentrations that exceed the screening levels, and chemicals for which no screening values are available, were identified as CoPCs. For all media, duplicate samples were averaged (using one-half the detection limit for non-detects[2]) for the data screening. The purpose of the screening exercise is to eliminate from further evaluation in the ecological risk assessment process those chemicals for which exposures are clearly unlikely to result in adverse ecological effects.

3.1 Available Site Data Sets

The most recent surface-water, sediment, and surface-soil data were compiled for the screening process to identify CoPCs. Earlier historical data were not used, because remedial actions have taken place at the site and the earlier data are therefore not representative of current conditions. Samples of surface water, sediment, and surface soil were collected in 2001 as part of the Phase I RCRA Facility Investigation (RFI). Surface water and sediment were also sampled in 2003 as part of the field studies conducted for the Supplemental ERA. In addition, 2008 surface-water data are available from the ongoing Comprehensive post-RI/FS monitoring program for the site. These data were used in the screening process to identify CoPCs for the site, and are summarized in the sections below.

Because metals are the site-related chemicals of concern, the evaluation of the existing data was limited to the following list of 19 metals:

[2] For summary statistics (mean, max), ½ detection limit was used for non-detects.

Aluminum	Antimony	Arsenic
Barium	Beryllium	Cadmium
Chromium	Cobalt	Copper
Iron	Lead	Manganese
Mercury	Nickel	Selenium
Silver	Thallium	Vanadium
		Zinc

3.1.1 Surface-water Data

The most recent surface-water data (2008) are available for Prickly Pear Creek and Lower Lake from the ongoing Comprehensive Post-RI/FS monitoring program for the site. Prickly Pear Creek monitoring station locations are identified as PPC-3A (upstream of the site), PPC-103 and PPC-5 (adjacent to the site), and PPC-7 and PPC-8 (below the site), and are shown on Figure 2.

Surface water from Prickly Pear Creek, Lower Lake, and Upper Lake was also collected in 2003 as part of the Supplemental ERA. Five stations were sampled in Prickly Pear Creek, including one upstream of the site (identified moving downstream as PPC 1 through 5). Three stations were sampled in Lower Lake (LL 1 through 3), and 12 stations were sampled in Upper Lake and the marsh area (ULM 1 through 12). These stations are identified on Figure 3, which is reproduced from the Supplemental ERA.

Surface-water samples were also collected in 2001 and 2002 from Upper Lake and Wilson Ditch as part of the Phase I RFI. Surface-water samples were collected at two historical Wilson Ditch monitoring locations: the ditch intake at Upper Lake (WD-1), and a monitoring point downgradient of the Asarco site (WD-2) (Asarco Consulting Inc. 2005). The Wilson Ditch monitoring locations are shown on Figure 2. Wilson Ditch was not included as part of the Supplemental ERA investigation.

The parameter list for surface-water monitoring at the site includes field-measured parameters (pH, specific conductance, dissolved oxygen, and water temperature), general physical parameters (total dissolved and suspended solids), major anions (e.g., sulfate, chloride), and total recoverable metals, as well as dissolved metals. For the Supplemental ERA, surface water was analyzed for the full suite of both total and dissolved metals; water hardness was also measured.

3.1.2 Sediment Data

Bulk sediment was collected and analyzed for metals in 2003 as part of the Supplemental ERA investigation. Sediment samples were collected from Prickly Pear Creek, Lower Lake, and Upper Lake and the marsh area, at the same stations identified above for surface water (refer to Figure 3). However, the 2003 Supplemental ERA did not include sediment data for Wilson Ditch.

3.1.3 Surface-Soil Data

Surface-soil samples were collected in 2001 as part of the Phase I RFI. For screening purposes, surface-soil[3] data were limited to those samples that were collected from unpaved or vegetated areas on the site. Samples from areas that have been remediated or areas that are covered (e.g., capped) were not included. The surface-soil sample locations are shown on Figure 4. Surface-soil samples that were used in the screening were collected from:

- Unpaved, vegetated portions of the Lower Ore Storage Area (identified as LOS)
- The area between Upper and Lower Lakes (also called Tito Park, identified as UOS)
- The railcar staging area (identified as RCSA)
- Unpaved areas within the site boundary (identified as UPS)
- Unpaved areas adjacent to the site boundary, or facility perimeter samples (identified as UOP).

[3] Only surface depth interval samples were included in the data screening. For the 2001 RFI data, this is typically the 0-4" interval, although some 0-1" samples were also included (refer to Table 5).

3.2 Literature Screening Values

To identify CoPCs, the surface-water, sediment, and surface-soil data were compared with ecological risk-based screening benchmarks identified from regulatory sources and the scientific literature. Screening benchmarks used in the identification of CoPCs are described further in the subsections below, as are the results of the screening for surface water, sediment, and surface soil.

3.3 Surface-Water Screening

To screen the data for potential effects on aquatic life, metals concentrations in surface-water samples collected from Prickly Pear Creek, Upper Lake, and Lower Lake were compared to Montana Department of Environmental Quality (MDEQ) acute and chronic numeric water quality standards for aquatic life, which are based on the most recent National Recommended Water Quality Criteria (NRWQC) published by EPA. For metals, the aquatic life standards are based on the analysis of samples following a "total recoverable" (i.e., "total metals") digestion procedure (MDEQ 2008), except for aluminum, which is based on dissolved concentrations. Site-specific water hardness was taken into account for cadmium, copper, chromium, lead, nickel, silver, and zinc, as specified in the standards (MDEQ 2008). The average hardness for all surface-water monitoring samples collected in April and October 2008, 100 mg/L, was used in the calculations for the hardness-dependent metals criteria.

The results of the surface-water historical data screening are presented in Table 3. Samples at all locations had dissolved aluminum concentrations below the detection limit. Samples with dissolved aluminum concentrations below the half detection limits of 100 mg/L exceeded the chronic water criteria. At Lower Lake, the mean and maximum concentrations of total arsenic exceeded chronic criteria. The mean and maximum concentrations of total cadmium, total copper, total mercury, and total selenium exceeded both of their respective acute and chronic criteria. The mean total lead concentration exceeded only chronic criteria. The maximum total lead and total zinc exceeded both acute and chronic criteria.

At Prickly Pear Creek, the detected mean total cadmium and detected mean and maximum total lead exceeded chronic criteria. The maximum total cadmium and mean and maximum total selenium were not detected but exceeded chronic criteria. The mean and maximum concentrations of total mercury were below the detection limit, but exceeded both acute and chronic criteria. The maximum total silver concentration was also below the detection limit but exceeded acute criteria.

At the Upper Lake/Marsh area, detected mean concentrations of total cadmium, copper, iron, lead, and selenium exceed the chronic criteria. The detected maximum concentration of total iron exceeded chronic criteria. The detected maximum concentrations of total cadmium, total copper, total lead, and total zinc exceeded both acute and chronic criteria. The maximum total selenium concentration was below detection limit, but exceeded chronic criteria.

At Wilson Ditch, detected mean total cadmium and total lead exceeded chronic criteria. The detected maximum total copper and total lead exceeded chronic criteria. The detected maximum total cadmium concentration exceeded both acute and chronic criteria.

At the reference area, detected mean concentrations of total cadmium, total iron, total lead, and total selenium exceeded chronic criteria. Detected maximum concentrations of total cadmium, total copper, total iron, and total lead exceeded chronic criteria. The mean and maximum total mercury were below the detection limit, but exceeded both acute and chronic criteria. The maximum total selenium was below the detection limit but exceeded chronic criteria, and the maximum total silver was below the detection limit but exceeded the acute criteria.

3.4 Sediment Screening

Sediment data were screened to identify CoPCs for potential effects on aquatic benthic macroinvertebrates. Metals concentrations in sediment samples collected from Prickly Pear Creek, Upper Lake, and Lower Lake were compared to freshwater sediment quality guidelines (SQGs), selected from lower-level threshold concentrations, including the consensus-based threshold effect concentrations (TECs) from MacDonald et al. (2000), the threshold effect levels (TELs) from Ingersoll et al. (1996), the Canadian interim sediment quality guidelines (ISQGs)

(CCME 2002), or the U.S. EPA (1996) threshold effect concentrations (TECs). Upper-level effect thresholds were also considered, including the MacDonald et al. (2000) probable effects concentrations (PECs), and the Ingersoll et al. (1996) and CCME (2002) probable effect levels (PELs).

It should be noted that these SQGs were generated using data from tests with field-collected sediments, which typically contain mixtures of contaminants, and additional information would be needed to identify the specific constituents that caused the observed toxicity (Ingersoll et al. 1996). The SQGs that were used for the sediment data screening are summarized below, in order of preferential use.

1. <u>MacDonald et al. (2000) TECs and PECs</u>. The MacDonald et al. (2000) SQGs are "consensus-based" values that are based on SQGs developed by others. TECs are intended to identify chemical concentrations below which adverse effects on benthic organisms would not be expected. TECs include TELs, lowest-effect levels (LELs), minimal effect thresholds, and sediment quality advisory levels. PECs are intended to identify chemical concentrations above which harmful effects on sediment-dwelling organisms are likely to be frequently or always observed. PECs include probable effects levels, effect range median values, and severe effect levels. TECs and PECs were calculated by MacDonald et al. (2000) by determining the geometric mean of the SQGs that were included in the threshold and probable effects categories, respectively.

2. <u>Ingersoll et al. (1996) TELs and PELs</u>. The Ingersoll et al. (1996) TELs and PELs were derived using laboratory data on the toxicity of contaminants associated with 28-day exposures to field-collected sediment for the amphipod *Hyalella azteca*. The TEL was calculated as the geometric mean of the lower 15th percentile of the effects concentrations and the 50th percentile of the no-effects concentrations. A TEL is assumed to represent a concentration below which toxic effects are rarely observed (Ingersoll et al. 1996).

3. <u>Canadian Council of Ministers of the Environment LELs (CCME 2002)</u>. As with the other SQGs, the CCME values were derived from co-occurring chemical and biological data from numerous individual studies using the National Status and Trends Program (NSTP)

approach (e.g., Long et al. 1995) to establish an association between the concentration of each chemical measured in sediment and any adverse biological effects. In addition, data derived using the spiked-sediment toxicity test (SSTT) approach are used to provide quantifiable cause-and-effect relationships between chemical concentrations in sediments and an observed biological response. Canadian full sediment quality guidelines are recommended if information exists to support both the modified NSTP and the SSTT approaches. Interim sediment quality guidelines (ISQGs) are recommended if information is available to support only one approach.

4. U.S. EPA (1996) TECs. These are consensus-based values derived from an evaluation of sediment effect concentrations for the amphipod *Hyalella azteca* and the midge *Chironomus riparius*, similar to the MacDonald et al. (2000) benchmarks.

The results of the sediment data screening are presented in Table 4. At Lower Lake, the mean and maximum arsenic, cadmium, lead, manganese, mercury, nickel, and zinc concentrations exceeded threshold-effect level SQGs. At Prickly Pear Creek, the mean and maximum arsenic, cadmium, lead, manganese, mercury, and zinc concentrations exceeded the screening values. At the Upper Marsh area, the mean and maximum arsenic, cadmium, lead, manganese, mercury, and zinc concentrations exceeded screening values. For iron, the maximum concentration exceeded the screening value. At the reference area, mean and maximum concentrations of arsenic, cadmium, lead, and zinc exceeded sediment screening values. Only the maximum manganese concentration exceeded the sediment screening value in the reference area.

3.5 Surface Soil Screening

The screening for potential effects of chemicals in surface soil on plants, soil biota, and wildlife was accomplished by comparing soil data from the site and adjacent areas to the U.S. EPA (2005a) ecological soil screening levels (Eco-SSLs) for plants, soil invertebrates, and wildlife, and the Oak Ridge National Laboratory (ORNL) toxicological benchmarks for plants, earthworms, and soil microbes (Efroymson et al. 1997a,b). The Eco-SSLs were developed to be protective of ecological receptors that contact soil or ingest biota that live in soil. Eco-SSLs were derived by EPA for plants, soil invertebrates, and wildlife by conducting literature searches, screening literature with exclusion and acceptability criteria, and scoring results for applicability in deriving an Eco-SSL (U.S. EPA 2005a). The toxicological benchmarks for plants (Efroymson et al. 1997b) were derived by ORNL by ranking growth and yield effect concentrations (at least 20% reduction in measured response) and picking the value that approximated the 10th percentile. The benchmarks for soil invertebrates (Efroymson et al. 1997a) were derived similarly, using a 20% reduction in growth, reproduction, or activity as the threshold for effects.

The lowest value for each chemical from the Eco-SSLs and the ORNL values was selected as the soil screening value for evaluating the historic surface soil data. As with other screening criteria, Eco-SSLs and the ORNL benchmarks were not intended for use as cleanup levels. Comparisons to these screening values were used to eliminate chemicals that clearly pose no risk to ecological receptors in soil from further evaluation in the ecological risk assessment process. Chemicals that exceeded the lowest available soil screening values were retained as soil CoPCs.

The results of the surface-soil data screening are presented in Table 5. Only arsenic, cadmium, copper, lead, and zinc were analyzed in surface soils. Nearly all detected samples in all locations exceeded the minimum soil screening criteria. Two samples in the Miscellaneous Unpaved Area had copper concentrations that did not exceed the criteria. Three samples in from the Perimeter and two samples at Tito Park did not exceed the arsenic and copper criteria. Several samples with cadmium concentrations below the detection limit of 5 mg/kg (or 2.5 mg/kg at half detection limit) exceeded the 0.36-mg/kg mammalian EPA ecological screening level (Eco-SSL).

4 Preliminary Conceptual Site Model

A conceptual site model (CSM) is a planning tool used for identifying chemical sources, potentially affected environmental media, complete exposure pathways, and potential receptors on which to focus the risk assessment. The ecological CSM describes the network of relationships between chemicals released from the site and the ecological receptors (plants and animals) that may be exposed to them through pathways such as ingestion of food or water. The CSM examines the range of potential exposure pathways and identifies those that are present and may be important for ecological receptors, and eliminates those pathways that are incomplete or insignificant and therefore do not pose a risk from further consideration in the ecological risk assessment process. This preliminary CSM was developed using information from previous investigations at the site, as well as information gathered during the 2008 site visit.

4.1 Site Description

From an ecological perspective, the facility site itself offers limited habitat for ecological receptors, with the exception of the onsite water bodies, Lower Lake and Upper Lake, and the marshes associated with Upper Lake. Prickly Pear Creek, which runs along the eastern boundary of the site, also provides aquatic and riparian habitat. The Wilson Ditch intake is at Upper Lake, and the ditch flows underground adjacent to the site. Wilson Ditch is a man-made diversion ditch for irrigation; it is only wet seasonally and does not provide permanent aquatic habitat. Very limited and low-quality terrestrial upland habitat is also available at the facility site, and is characterized by sparsely vegetated disturbed areas such as the area between Lower and Upper Lakes. Figure 5 provides an aerial photo of the site that identifies these habitat features.

For ecological receptors, future exposures are not expected to differ significantly from current exposures. Potential future uses do not preclude existing exposure pathways in Lower Lake, Upper Lake, Upper Lake Marsh, and Prickly Pear Creek, and onsite terrestrial pathways would be made incomplete by capping and revegetation under the agricultural or recreational use scenarios. Ecological exposures under the industrial future use scenario would not differ from present, or baseline, conditions.

Numerous investigations and remedial actions have taken place at the site from the late 1980s tithe present. Table 6 summarizes the remediation-related activities that have taken place, which have altered site conditions over time. Soil and sediment removal actions, changes in facility discharges, installation of treatment systems and Geomembrane caps, and stormwater improvements are some of the remedial actions that have changed conditions and potential exposures at the facility over the past 20+ years.

The primary habitat features at the site are the surface-water bodies, Prickly Pear Creek, Lower Lake, Upper Lake, and the marshes surrounding Upper Lake (refer to Figure 5). Surface-water flow at the site is diverted from Prickly Pear Creek at the Upper Lake diversion, upstream of the Asarco facility site, and is regained by return surface-water flow from Upper Lake, and groundwater inflow in the vicinity of Lower Lake. Water quality data and groundwater levels show evidence of stream-flow loss in the area immediately downstream of the Asarco facility site. Dissolved and total metal concentrations have historically shown elevations in the reach of Prickly Pear Creek adjacent to the Asarco site. This increase has been attributed to historical seepage from Lower Lake via groundwater in the stream reach immediately adjacent to Lower Lake. However, upstream historical mining activities and other sources also contribute to metal loading in Prickly Pear Creek and its associated drainage. These water bodies and associated habitat are described further in the sections below.

4.1.1 Prickly Pear Creek

Prickly Pear Creek flows along the eastern site boundary, north toward the town of East Helena (refer to Figure 1). Prickly Pear Creek is located in the Lake Helena watershed of the Upper Missouri river basin. The headwaters of Prickly Pear Creek are in the Elkhorn Mountains, and flow is east and north through the Helena Valley to Lake Helena, and then on to the Missouri River (Montana Water Trust 2008). Prickly Pear Creek meets the confluence with Ten Mile Creek one mile upstream of Lake Helena.

Prickly Pear Creek has been a source of water for agriculture, mining, and industrial use for more than a century (Asarco Consulting Inc. 2005), and its water quality is monitored regularly as part of Asarco's Comprehensive Post-RI/FS monitoring program for the site. The creek suffers numerous water quality impairments due to metals, sediment loads, nutrients, high temperatures, and lack of instream flow. Prickly Pear Creek is listed as chronically dewatered by the Montana Department of Fish, Wildlife and Parks (MFWP), and the MDEQ has issued numerous Total Maximum Daily Loads (TMDLs), or beneficial use impairments for the stream (Montana Water Trust 2008).

Data on TMDLs and designated uses of Prickly Pear Creek were obtained from EPA's Water Quality Assessment and TMDL information website.[4] The overall status of Prickly Pear Creek is listed as "Impaired" as of reporting year 2006. Designated use groups with impaired status for the creek are listed as agricultural, aquatic life, cold water fishery, drinking water, industrial, primary contact recreation, and warm water fishery. The causes of impairment in Prickly Pear Creek are listed as alteration of riparian vegetation, ammonia inputs, metals, low-flow alterations, nutrient inputs, substrate alterations, sedimentation, and temperature impacts. EPA's Water Quality Assessment listed sources that are likely contributing to impairment in the creek, including acid mine drainage and impacts from abandoned mine lands, sediment contamination due to legacy/historical pollutants, grazing in riparian zones, habitat modification, irrigation demands, and municipal treatment systems.

TMDL data for Prickly Pear Creek are organized into eight separate stream reaches. Three reaches encompass Prickly Pear Creek from the headwaters down to about 2 miles downstream of the site. These reaches are:

- Headwaters to Spring Creek
- Spring Creek to Lump Gulch
- Lump Gulch to Montana Highway 433 (Wylie Drive, includes the site reach).

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[4] http://iaspub.epa.gov/tmdl_waters10/attains_waterbody.control?p_list_id=MT41I006_030&p_cycle=2006

The reach from Lump Gulch to Montana Highway 433 covers about 4 miles of creek, with the site approximately in the middle of the reach. The TMDLs described below apply to the entire Prickly Pear Creek watershed. TMDLs reported below are carried over from upstream reaches into reaches downstream.

- For the Headwaters to Spring Creek reach, TMDLs exist for lead (67 lb/yr) and sediment (54 tons/yr).
- For the Spring Creek to Lump Gulch reach, TMDLs exist for cadmium (12 lb/yr), lead (67 lb/yr), sediment (54 tons/yr), and zinc (1977 lb/yr).
- For the Lump Gulch to Montana Highway 433 reach, TMDLs exist for arsenic (149 lb/yr), cadmium (12 lb/yr), copper (149 lb/yr), lead (67 lb/yr), sediment (54 tons/yr), thermal modifications (≤1 °F when water temperature is <67 °F), and zinc (1977 lb/yr).

According to the Comprehensive RI/FS (Hydrometrics 1990), the creek is influenced by acid mine drainage in mining areas toward its headwaters, and by railroad and highway construction, residential subdivision development, agricultural diversion and dewatering, and municipal and industrial discharges. From July through September, Lower Prickly Pear Creek downstream of East Helena is severely dewatered by irrigation demands, and during this time, it often becomes nearly or completely dry. The creek supports a trout fishery upstream of East Helena, but summer dewatering and sewage treatment effluents severely limit the creek's ability to support trout downstream of East Helena. In 2008, the Montana Water Trust coordinated a successful "water swap" that resulted in restoring flow in Prickly Pear Creek below East Helena. As a result of increased flows, the creek's thermal impairments were reduced significantly (Montana Water Trust 2008).

Fish species expected to occur in Prickly Pear Creek include brook trout, brown trout, longnose sucker, mottled sculpin, rainbow trout, walleye, white sucker, and longnose dace.

Base flow in Prickly Pear Creek is typically 25 to 30 cfs. Peak flows near the site during spring and early summer runoff have ranged from near 50 cfs to greater than 300 cfs. In general, Prickly Pear Creek is characterized by alkaline pH (average pH values for individual water quality monitoring stations range from 6.8 to 8.2), and moderately low concentrations of dissolved solids (average TDS ranges from 158 to 192 mg/L). Freshwater chronic criteria for manganese and lead are typically exceeded both upstream and downstream of the site. Occasional exceedances of water quality standards for arsenic, cadmium, copper, and zinc have also been documented during monitoring upstream and downstream of the site. In general, downstream sediment arsenic and metals concentrations are higher than those upstream of the site. The supplemental ERA concluded that risks to fish and benthic invertebrates in Prickly Pear Creek were minimal to low (U.S. EPA 2005b). Sediment toxicity tests were not conducted for the creek, but a macroinvertebrate community analysis indicated that stations downstream of the site may have lower numbers of total and sensitive taxa compared to upstream areas, although data were limited (U.S. EPA 2005b).

The supplemental ERA (U.S. EPA 2005b) concluded that exposure to metals in Prickly Pear Creek may cause adverse effects in insectivorous (insect-eating) birds, waterfowl, and piscivorous (freshwater-fish-eating) birds. However, similar risks were estimated for the Prickly Pear Creek station upstream of the site (the reference site).

Seepage from Lower Lake via groundwater historically contributed to increased metals concentrations in the creek adjacent to the site. Although the Prickly Pear Creek channel is immediately adjacent to the slag pile, and erosion of slag is possible during extremely high flow events, long-term monitoring has not indicated measurable impacts on water quality over this reach due to the slag. The Comprehensive RI/FS (Hydrometrics 1990) concluded that the only measurable impacts from the site to Prickly Pear Creek water quality were from seepage from Lower Lake.

Synoptic streamflow measurements have been recorded seasonally in Prickly Pear Creek over the past several years. Primary surface-water monitoring sites in the vicinity of Lower Lake where flow measurements are obtained regularly include (in upstream to downstream order) PPC-3A, PPC-103, and PPC-5 (Figure 2). Streamflow data from these sites indicate that rates of groundwater recharge to the creek (or creek losses to groundwater) are small in comparison to the overall streamflow rates. Similar to the streamflow data, the surface-water and groundwater quality data suggest that any influence of groundwater on the creek water quality is subtle.

4.1.2 Lower Lake

Lower Lake is a man-made impoundment that was historically a holding pond for process fluids from the smelter operations. The lake was formed in the 1940s by dividing the northern portion of Upper Lake with a berm of fill, for the purpose of storing process recirculation water (Asarco Consulting Inc. 2005). Lower Lake sediments were removed in 1996 as part of the facility remedial actions, and the dredged materials were smelted at the facility or placed in an onsite landfill. Despite this removal action, surface-water and sediment samples collected in 2003 for EPA's Supplemental ERA (U.S. EPA 2005b) showed elevated levels[5] of metals, including arsenic, cadmium, copper, lead, manganese, mercury, selenium, silver, thallium, and zinc. In addition, a 10-day subchronic toxicity test conducted as part of the supplemental ERA that measured amphipod (*Hyalella azteca*) survival and growth demonstrated reduced survival from exposure to Lower Lake sediment. Average amphipod survival for exposure to Lower Lake sediment was 75%, compared to 92.5% for the control and 90% to 95% for the Canyon Ferry Reservoir[6] reference site.

Based on exceedances of water quality criteria and sediment screening values, and the results of the subchronic toxicity test, the supplemental ERA (U.S. EPA 2005b) concluded that fish and benthic invertebrates are at risk of population-level effects. However, Lower Lake is not a natural surface-water feature, and it is not known whether it provides habitat for aquatic receptors such as fish and benthic invertebrates. The lake has a gravel and sand bottom, an absence of shoreline and aquatic vegetation, and appears to provide very poor aquatic habitat. During the September 2008 site visit, waterfowl were observed loafing, though not feeding, on Lower Lake, and there are some reports of turtles occurring there. The supplemental ERA concluded that there were risks of adverse effects to insectivorous birds, waterfowl, and piscivorous birds and mammals due to incidental ingestion of sediment in Lower Lake (U.S.

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5 In excess of ambient water quality criteria and sediment toxicity benchmark values.

6 Canyon Ferry Reservoir is an impoundment of the Missouri River, located about 20 miles east of Helena, Montana.

EPA 2005b). Tissue data for prey items from Lower Lake were not available, and it is not known whether prey items such as invertebrates and fish are present.

South of Lower Lake, between Lower Lake and Upper Lake (refer to Figure 5), is a disturbed, sparsely vegetated area that provides minimal upland habitat. The soils in this area are disturbed, and there is little cover for ecological receptors. Due to the availability of more desirable habitat in the marsh area surrounding Upper Lake and along the riparian edge of Prickly Pear Creek, it is unlikely that this disturbed area receives substantial use by ecological receptors. Upland habitats are discussed in Section 4.1.5.

The relationship between Prickly Pear Creek and Lower Lake is important, due to the proximity of Lower Lake to Prickly Pear Creek and the historical use of Lower Lake as a storage pond for excess process water. Extensive water resources monitoring has been conducted in the vicinity of Lower Lake since at least 1985. The seasonal water resources monitoring has generally included collection of groundwater and surface-water elevation data, streamflow monitoring in Prickly Pear Creek, and water quality sampling in Lower Lake, Prickly Pear Creek, and the intervening groundwater system. Review and interpretation of this data have been presented in previous documents, including Hydrometrics (1999) and ACI (2005).

4.1.3 Upper Lake and Marshes

Upper Lake and its associated marshes lie at the southern end of the property (refer to Figure 5). Upper Lake was formed from a diversion of Prickly Pear Creek about one-half mile south of the site. A portion of the water diverted from Prickly Pear Creek to Upper Lake was historically used by the Asarco facility. The remainder of the water is either routed through Wilson Ditch and used for agricultural purposes (stock watering and irrigation) in the area to the northwest of the site, or returned to Prickly Pear Creek through an overflow structure.

The supplemental ERA (U.S. EPA 2005b) provides the following description of Upper Lake and the marsh. Upper Lake is reported to range in depth from about 5 to 12 ft. The emergent marsh area is covered with water ranging from a few inches to 2 ft deep. The sediment in the marsh is reported to be anaerobic, which would be typical for this type of environment. From general observations made during the September 2008 site visit, the sediment in the lake appears to be fine-grained and mucky, and the lake supports emergent and submerged aquatic vegetation. During the site visit, the water in Upper Lake was lower than average due to beaver (*Castor Canadensis*) activity along Prickly Pear Creek, creating some open mudflat areas. Waterfowl, pelicans (*Pelecanus erythrorhynchos*), and shorebirds were observed at Upper Lake during the September 2008 site visit. Evidence of foraging (footprints) by raccoons (*Procyon lotor*) along the lake edge was also observed.

Bird counts and observations recorded by volunteers for the Audubon Society reported a sandhill crane with young and a female common merganser with brood in 1992 and 1993, respectively, at the "Asarco ponds." In 1993, Audubon volunteers reported seven species of waterfowl here, including Canada goose (*Branta canadensis*), common merganser (*Mergus merganser)*, green-winged and cinnamon teal (*Anas carolinensis* and *A. cyanoptera*), mallard (*A. platyrhynchos*), ring-necked duck (*Aythya collaris*), and ruddy duck (*Oxyura jamaicensis*). Twenty-four species of songbirds were also recorded in 1993, including tree, cliff, and barn swallows (*Tachycineta bicolor*, *Petrochelidon pyrrhonota*, and *Hirundo rustica*); belted kingfisher (*Megaceryle alcyon*); American robin (*Turdus migratorius*); red-winged blackbirds (*Agelaius phoeniceus*); and others. Observations of fish-eating shorebirds such as double-crested cormorants (*Phalacrocorax auritus*), great blue herons (*Ardea herodias*), and great egret (*Ardea alba*) were also recorded at this time, as well as raptors, including osprey (*Pandion haliaetus*) and red-tailed hawk (*Buteo jamaicensis*).

A qualitative assessment of wildlife use of Upper Lake wetlands (called Upper Lake Marsh) was conducted in 1988 and is provided in an appendix to the Comprehensive RI/FS (Hydrometrics 1990). This report also provides information on the habitat types around Upper Lake. Emergent wetlands consisting primarily of cattails (*Typha* spp.), and forested wetlands including dominant plant species such as aspen (*Populus tremuloides*) and cottonwoods (*Populus deltoides*) were recorded around Upper Lake, and also upland grassland habitat consisting of blue grama (*Bouteloua gracilis*), needle-and-thread (*Stipa comata*), bluebunch wheatgrass (*Agropyron spicatum*), bluegrass (*Poa* spp.), wheatgrass (*Agropyron* spp.), and cheatgrass (*Bromus tectorum*). This assessment identified approximately 20 species of mammals and 60 species of birds in the vicinity of Upper Lake. Fish species expected in Upper Lake include brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*), common carp (*Cyprinus carpio*), fathead minnow (*Pimephales promelas*), largemouth bass (*Micropterus salmoides*), longnose dace (*Rhinichthys cataractae*), longnose sucker (*Catostomus catostomus*), mottled sculpin (*Cottus bairdi*), mountain whitefish (*Prosopium williamsoni*), rainbow trout (*Oncorhynchus mykiss*), smallmouth bass (*Micropterus dolomieui*), stonecat (*Noturus flavus*), walleye (*Sander vitreus*), white sucker (*Catostomus commersonii*), and yellow perch (*Perca flavescens*).

Data from the Comprehensive RI/FS (Hydrometrics 1990) showed that water quality in Upper Lake was essentially the same as Prickly Pear Creek upstream of the Asarco site. As noted in the Comprehensive RI/FS, historical mining impacts are well documented and are a major source of metals to Prickly Pear Creek. Elevated concentrations of metals occur in Upper Lake sediments, with higher concentrations than those in Prickly Pear Creek both upstream and downstream of the site. This is not surprising, given that the lentic conditions in Upper Lake allow settling and accumulation of fine sediments from the creek upstream of the site.

Sediment concentrations of arsenic, cadmium, copper, lead, mercury, silver, and zinc exceeded sediment toxicity benchmarks in Upper Lake, based on the data collected for the supplemental ERA (U.S. EPA 2005b). However, the sediment toxicity tests showed that average survival of the amphipod *H. azteca* exposed to Upper Lake sediment was not different from the laboratory control or the reference site.

The supplemental ERA concluded that risks to fish and benthic invertebrates in Upper Lake were minimal to low, but that risks of adverse effects to wildlife receptors (insectivorous birds, waterfowl, and piscivorous birds and mammals) exist, particularly from incidental ingestion of sediment (U.S. EPA 2005b). However, EPA (2005b) notes that their risk estimates were based on a limited data set, and that there is low confidence in their conclusions. They recommend collecting data to provide additional lines of evidence to "better assess the accuracy of these risk predications." U.S. EPA (2005b) also identifies antimony, beryllium, cadmium, copper, lead, selenium, and silver as having inadequate detection limits to assess potential risk.

4.1.4 Wilson Ditch

Wilson Ditch is used to convey irrigation and stock water from Prickly Pear Creek to fields northwest of the site. Corrective measures previously implemented for Wilson Ditch included removal of bottom sediments in the open channel, and replacement of the Asarco site segment of the ditch with an underground pipeline routed south of the Asarco site in 1997. The new ditch route from Upper Lake eliminated the potential for water from the site to affect Wilson Ditch. Phase I RFI data collected in 2001 and 2002 show that water quality in Wilson Ditch downstream of the Asarco facility remains the same as in Upper Prickly Pear Creek.

In Wilson Ditch, water flows only during the irrigation season (approximately April through September). Measured flows in the ditch during the times that it contains water are low, and have ranged from 1.46 to 8.26 cfs. It is not known whether Wilson Ditch provides habitat for aquatic receptors such as fish and benthic macroinvertebrates during extended wet periods. Wilson Ditch was not evaluated in the Supplemental ERA.

4.1.5 Upland Areas

Smelter operations and emissions may have affected terrestrial uplands both on and off the site. Terrestrial habitat at the site is limited to onsite areas near buildings, former operations and stockpile areas, including the area between Lower and Upper Lakes (also called "Tito Park"), and the open ranchland adjacent to the site (Figure 5). The onsite areas may provide limited habitat for common species such as rabbits, squirrels, mice, and pigeons. White-tailed deer have been reported on the facility. The adjacent ranchland, which may have been affected by historical smelter emissions, likely provides habitat for deer, small mammals, upland game birds such as grouse and partridge, sparrows, and predators, including red-tailed hawks, coyotes, and foxes, in addition to supporting livestock (primarily cattle).

Remediation activities in the area between Upper and Lower Lake, also referred to as Tito Park, began in 1991/92 with removal of the acid-plant sediments from the sediment drying pad in the extreme western portion of this area (Table 6). In 2001, additional stockpiled soils and debris piles were removed from the area between Upper and Lower Lake and placed in the Phase I Corrective Actions Management Unit (CAMU). The area was then regraded and capped with

12 inches of clay soil obtained from the Phase I CAMU clay liner stockpile (permeability of 10^{-7} cm/sec or less). The clay cap is graded so that stormwater runoff drains westward to the site, where the runoff is collected for treatment in the facility water treatment plant. Various grasses and shrubs have since colonized the area, resulting in a sparse vegetative cover.

In 2006, a slurry wall was constructed in the extreme western portion of the site to isolate subsurface soils in the former acid plant area (Asarco 2008). The slurry-wall area is covered with a temporary plastic liner about 1 acre in area, and the temporary cap is to remain in place until a final site cap is constructed. No additional disturbance is proposed in the Upper/Lower Lake area, except for the test-pit soil sampling proposed in the Phase II RFI Technical Memorandum.

4.2 Sensitive Species

The remedial investigation of soils, vegetation and livestock (CH2MHill 1987a), states that no endangered plant or animal species are known to exist in the Helena Valley, but there is potential for migratory bald eagles (*Haliaeetus leucocephalus*) and peregrine falcons (*Falco peregrinus*, no longer listed in Montana) to enter and make use of habitat in the Helena Valley. Endangered, threatened, proposed, and candidate species have been listed for each Montana county by FWS and the Montana Natural Heritage Program (MNHP). The following species are listed by FWS for Lewis and Clark County (U.S. FWS 2006):

- Bald eagle
- Grizzly bear (*Ursus arctos horribilis*)
- Gray wolf (*Canis lupus*)
- Canada lynx (*Lynx canadensis*)
- Bull trout (*Salvelinus confluentus*)
- Black-footed ferret (*Mustela nigripes*).

MNHP (2009) lists 61 Species of Concern for Lewis and Clark County (Table 7). Threatened and endangered species and Montana Species of Special Concern are not expected to occur at the site or in the surrounding areas. However, reviews of the site and surrounding areas will be requested from FWS and MNHP as part of the Phase I BERA.

4.3 Exposure Pathways

An exposure pathway is the course that a chemical takes from a source to an exposed receptor. A complete exposure pathway consists of the following four elements:

1. A source
2. A mechanism of release, retention, or transport of a chemical to a given medium (e.g., sediment, water, soil)
3. A point of contact with the medium (i.e., exposure point)
4. A route of exposure at the point of contact (e.g., incidental ingestion, direct contact).

If any of these four elements are missing, the pathway is considered incomplete (i.e., it does not present a means of exposure). Only those exposure pathways judged to be potentially complete are of concern and require evaluation in the BERA. Additionally, exposure to naturally occurring metals is likely throughout the area, both beyond and within the Asarco site, through the pathways described above. Background exposure will be characterized by also measuring or estimating exposure at upstream and/or reference locations.

The preliminary CSM (Figure 6) for the BERA describes possible sources and transport mechanisms of metals from the facility into surrounding ecosystems, and the pathways by which ecological receptors may be exposed to those metals. The preliminary CSM was developed based on the site history, site conditions, prior investigations including the 2005 Supplemental ERA, and the results of available sample analyses.

The sources of contaminants (metals) at the site are former stack and fugitive emissions, process fluids, slag, and other wastes from historical smelter operation. Metals can be released from these sources via the transport mechanisms of wind and aerial deposition, surface-water runoff and soil erosion, and leaching to groundwater. Once released to the environment, some of the metals may become dissolved or suspended in surface water, co-deposited with or adsorbed to sediments, incorporated into soil, leached into groundwater, and potentially can enter the food web through uptake into plants and prey, which then could be consumed by upper-trophic-level ecological receptors.

Potential pathways exist by which ecological receptors may be exposed to metals associated with the site, for both aquatic and terrestrial communities in the vicinity of the facility, as illustrated in the preliminary ecological CSM (Figure 6).

Surface water and sediment may be affected by direct discharge (such as historical discharges to Lower Lake, a former process pond), surface runoff, and groundwater discharge to surface water. Aquatic ecological receptors (fish and benthic invertebrates) may come in contact with metals in the sediments and surface water of Prickly Pear Creek, Lower Lake, Upper Lake, Upper Lake Marsh, and possibly Wilson Ditch, through direct contact and ingestion of contaminated aquatic plants or prey.

Discharge from groundwater to surface water may also be an important pathway for exposure of aquatic organisms. According to the Phase I RFI, metals from historical site activities are present in groundwater beneath the site. Based on hydrogeologic information, the direction of groundwater flow beneath the site is generally to the north and northwest. However, local groundwater flow to Prickly Pear Creek occurs as seepage from Lower Lake through the earthen berm that separates the pond and the creek. As a result, there is a component of groundwater flow on the northeast side of Lower Lake that flows toward Prickly Pear Creek. Although groundwater flow at the Lower Lake berm is evident, there appears to be little interaction between groundwater and Prickly Pear Creek north of Lower Lake.

For terrestrial plants, the primary pathway is the uptake or absorption of metals incorporated into soil, and uptake via sediment and surface water for aquatic and wetland plant species. Soil fauna (represented by soil invertebrates) may also be exposed to metals through direct contact with the soil.

Primary exposure pathways for wildlife receptors in the aquatic environments include the ingestion or uptake of surface water, consumption of contaminated plant material or prey, incidental ingestion of sediment during foraging or preening, and direct contact with surface water and sediment. Direct contact with sediment and surface water is a potential exposure pathway for wildlife receptors, but this route is insignificant relative to the ingestion route. Therefore, the exposure pathways for wildlife receptors that will be investigated include indirect exposure via ingestion of metals in plants and prey, and direct and incidental ingestion of metals in surface water, sediment, and surface soil.

4.4 Ecological Receptors

Potential ecological receptors that may be exposed to metals from the site occur in terrestrial systems such as vegetated upland areas around the facility perimeter (and the sparsely vegetated area between Lower and Upper Lakes, also referred to as "Tito Park"), the marshes surrounding Upper Lake, and the riparian corridor along Prickly Pear Creek, as well as in aquatic systems including Prickly Pear Creek, and Upper and Lower Lakes.

Categories of ecological receptors that are potentially affected include terrestrial plants, aquatic and wetland plants, soil fauna, aquatic invertebrates, reptiles and amphibians, fish, birds, and mammals. Each category encompasses a range of functional groups, such as terrestrial insectivores or piscivores, which differ by habitat utilization and food preferences. The particular species composition of aquatic and terrestrial communities varies among habitats at the facility.

The selected representative receptors represent the types of organisms most likely to encounter the CoPCs at the Upper and Lower Lakes, Prickly Pear Creek, Upper Lake Marsh, Wilson Ditch, and upland habitats at the site. These receptors include a reasonable (though not comprehensive) cross section of the major functional and structural components of the ecosystem under study, based on:

- Relative abundance and ecological importance within the selected habitats
- Availability and quality of applicable toxicological literature
- Relative sensitivity to the CoPCs
- Trophic status
- Relative mobility and local feeding ranges
- Ability to bioaccumulate CoPCs.

The approach for selecting representative species for assessing wildlife exposures is a common practice for assessing ecological risk. The selected species are chosen to represent different feeding guilds. A guild is a group of animals within a habitat that use resources in the same way. Coexisting members of guilds are similar in terms of their habitat requirements, dietary habitats, and functional relationships with other species in the habitat. The guild approach allows focused integration of many variables related to potential exposure. These variables include characteristics of CoPCs (toxicity, bioaccumulation, and mode of action) and characteristics of potential receptors (habitat, range, feeding requirements, and relationships among species). This approach evaluates potential exposures to all animals by considering the major feeding guilds found in a habitat. It is assumed that evaluation of the potential effects of CoPCs on the representative species will indicate the potential effects of CoPCs to other species within each feeding guild.

The site provides habitat for a variety of fish, benthic invertebrates, reptiles and amphibians, small mammals, piscivorous birds and mammals, and songbirds. Foraging animals such as mice, voles, and shrews likely forage in the Upper Lake Marsh and in the Prickly Pear Creek riparian zone. It is not possible to quantitatively assess all receptors or receptor categories. For example, toxicity data for reptiles and amphibians are very limited for most metals, and therefore this receptor class (i.e., herpetofauna) will only be assessed qualitatively. The representative receptors selected for the BERA are:

- Fish (forage species, piscivorous species, game species)
- Benthic macroinvertebrates
- Upland and wetland plants
- Soil invertebrates
- Belted kingfisher
- Mallard
- Tree swallow
- Mink (*Neovison vison*)
- Short-tailed shrew (*Blarina brevicauda*)[7]
- American robin.

Fish are important receptors at the site, because they are in direct contact with surface water, are known to occur at the site in Upper Lake and Prickly Pear Creek, provide a prey base for piscivorous birds and mammals, and are of societal value. Fish may also occur at Lower Lake and Upper Lake Marsh, although their presence or absence is currently unknown.

Benthic invertebrates are important receptor species for Prickly Pear Creek, Upper Lake, and Upper Lake Marsh, because they have the greatest potential exposure to metals in sediments; provide food for fish, mammals, and birds; and are relatively immobile (sessile) in habit, and therefore, their general health and condition reflects conditions in the immediate area of the site. The presence of benthic invertebrates at Lower Lake and Wilson Ditch is currently unknown.

Terrestrial and wetland plant communities, and soil faunal communities are important indicators of ecosystem health; they are in direct contact with metals in soil and sediment (and surface

7 Short-tailed shrew is listed as a species of concern for the State of Montana; however, information on its range within the state is not available. Although it is not known whether this species occurs in Lewis and Clark County, receptor characteristics are available for this species for food-chain modeling, and it can serve as a surrogate for other shrew species that might occur at the site.

water in the case of wetland or aquatic plants), and they represent the base of the aquatic and terrestrial food chains. Plant communities are important to assess for the upland areas at the site and Upper Lake Marsh.

Piscivorous birds and mammals, waterfowl, songbirds, and small mammals that consume biota at lower levels of the food chain are important receptor species for both aquatic, wetland, and upland areas at the site, because they are exposed to contaminants through multiple media (e.g., sediment, surface water, wetland soil, plants and prey), represent higher trophic levels, and thus provide an estimate of risk from bioaccumulative chemicals.

4.5 Assessment Endpoints and Ecological Risk Management Goals

This section presents the rationale for selection of the assessment endpoints for the BERA, and also discusses the ecological risk management goals for the site. EPA states that "assessment endpoints focus the risk assessment on particular components of the ecosystem that could be adversely affected by contaminants from the site" (U.S. EPA 1997). Ecological risk management goals are defined as a general statement about the desired condition of ecological values of concern (U.S. EPA 1998). The selection of the assessment endpoints should reflect the ecological risk management goals for the site. The overall risk management goal for the site is to reduce ecological risks, if necessary, to levels that will result in the maintenance of healthy local populations and communities of biota. This is consistent with the first principle of ecological risk management outlined by U.S. EPA (1999) in their guidance: *Ecological Risk Assessment and Risk Management Principles for Superfund*. Specific ecological risk management goals for the East Helena facility are to:

- Sustain healthy local populations of birds and mammals that use habitat associated with Prickly Pear Creek, Lower Lake, Upper Lake and marshes, Wilson Ditch, and upland habitats at and surrounding the facility site.

- Maintain healthy, viable fish populations in Prickly Pear Creek, Upper Lake, and Upper Lake Marsh (it is not known whether habitat conditions in Lower Lake support a fish community).
- Maintain diversity of healthy native communities of biota, including plant communities and aquatic habitat-dependent wildlife.

The selection of the assessment endpoints considered ecologically relevant receptor groups that are potentially highly exposed to the chemicals of concern, attributes of the natural history of these receptors, and potentially complete exposure pathways (U.S. EPA 1997). The assessment endpoints for the BERA are:

1. Survival, growth, and reproduction of benthic invertebrate populations in Prickly Pear Creek, Lower Lake, Upper Lake, Upper Lake Marsh, and possibly Wilson Ditch
2. Survival, growth, and reproduction of fish populations in Prickly Pear Creek, Lower Lake (if fish are present), Upper Lake, and Upper Lake Marsh
3. Survival, growth, and propagation of terrestrial and wetland plant communities in upland vegetated areas onsite, in the upland areas around the site perimeter, in Upper Lake Marsh, and in the riparian zone of Prickly Pear Creek
4. Survival of soil faunal communities in upland habitat areas onsite and around the site perimeter
5. Survival and reproduction of avian and mammalian wildlife populations that frequent Prickly Pear Creek, Lower Lake, Upper Lake, Upper Lake Marsh, Wilson Ditch, and upland areas onsite and in areas around the site perimeter.

4.6 Risk Questions and Measures of Effect

Ecological risk questions should be based on the assessment endpoints and provide a basis for developing the study design, and for evaluating the results of the site investigation in the analysis phase and during risk characterization (U.S. EPA 1997). The BERA has been designed to answer the following ecological risk questions for the site, now and under future use scenarios:

- Do site-related metals in the surface water and sediment of Prickly Pear Creek (and hyporheic[8] water of the creek), Upper Lake, Upper Lake Marsh, Lower Lake (and possibly Wilson Ditch) have the potential to adversely affect benthic invertebrate and fish populations?

- Have site-related metals in surface soil (and sediment in the case of wetland areas) been accumulated by plants and invertebrates? Do they have the potential to adversely affect soil fauna and plant communities onsite, in the Upper Lake Marsh, along Prickly Pear Creek, and in areas adjacent to the facility?

- Do site-related metals in surface water, sediment, surface soil, plants, and prey items have the potential to adversely affect avian and mammalian wildlife populations that frequent Prickly Pear Creek, Upper Lake, Upper Lake Marsh, Lower Lake, Wilson Ditch, and upland areas on and adjacent to the site?

Measurement endpoints, or measures of effect, are used to answer the risk questions for each assessment endpoint. Measures of effect, or measurement endpoints, are measurable characteristics that reflect the assessment endpoint (U.S. EPA 1997). In a weight-of-evidence approach, multiple measures of effect are examined for each assessment endpoint. Table 8 summarizes the measures of exposure and effect for each assessment endpoint and exposure

[8] The hyporheic zone is defined as a subsurface volume of sediment and porous space adjacent to a stream through which stream water readily exchanges. Subsurface water in this zone is "hyporheic water."

area for the BERA. These include measures of exposure, measures of effect, and measures of receptor and ecosystem characteristics:

- Habitat characterization and ecological community observations to verify exposure pathways, characterize use of each habitat or exposure area by ecological receptors, and make observations regarding habitat quality and ecosystem and plant community health.
- Comparison of measured environmental concentrations in surface soil and sediment to screening benchmark values published in the scientific literature, technical literature, or government documents (such as SQGs and EPA's EcoSSLs); and measured concentrations in surface water (and hyporheic water of Prickly Pear Creek) compared to Montana Numeric Water Quality Standards for Aquatic Life.
- Chemical and physical parameter measures such as pH, total organic carbon (TOC), acid volatile sulfide (AVS), and simultaneously extracted metals (SEM), and grain size for sediment.
- Site-specific sediment toxicity tests to evaluate the effects of metals on survival, growth, and/or reproduction of benthic invertebrates in Prickly Pear Creek.
- Measured concentrations of metals in sediment, prey fish, benthic invertebrates, and larger predatory fish, to evaluate exposure and the potential for adverse effects on the survival and reproduction of higher-trophic-level fish.
- Wildlife exposure estimates from food-chain modeling (using measured concentrations in plant and prey items, surface water, sediment, and surface soil) compared to toxicity reference values (TRVs) from the scientific literature for endpoints related to survival and reproduction.

- Statistical comparisons of measures of exposure and effects from areas affected by site-related metals to reference sites.

5 Phase I Ecological Site Investigation (2009)

The Phase I ecological site investigation is planned for the 2009 field season to provide data for use in the draft BERA. The outcome of the Phase I studies and the draft BERA will determine the necessity for any additional studies that might be conducted in a second phase (Phase II) of the BERA in 2010.

As recommended in the U.S. EPA (1997) guidance, tissue residue studies will be conducted on organisms that are in the exposure pathway (i.e., part of the food chain) associated with each assessment endpoint to minimize the uncertainty associated with estimating a dose (or intake) for each wildlife receptor species. Concentrations of metals in prey/food should be linked to an exposure concentration from a contaminated medium (e.g., soil, sediment, water), because it is the medium, not the food-chain items, that will ultimately be remediated, if necessary (U.S. EPA 1997). Therefore, metal concentrations will be measured in environmental media at the same locations where organisms will be collected, from both the site and reference locations. Collocated samples of surface water, sediment, and surface soil will be collected to determine whether a correlation exists between the tissue residue levels and concentrations of contaminants in the environmental media. Data collection for the Phase II RFI site characterization will be coordinated with the Phase I ecological field studies, because site characterization and risk assessment data needs coincide for certain parameters (e.g., surface-water, sediment, and surface-soil sampling).

5.1 Habitat Characterization

A habitat characterization will be conducted to determine the size and quality of potentially affected habitats, the extent to which the habitats are connected to other open land, wildlife use of habitats, and the potential for effects on species or habitats of special concern. The intent of the habitat characterization is to:

- Refine the ecological CSM and focus the current Phase I and subsequent field investigations in Phase II of the BERA, if necessary

- Verify exposure pathways and presence of receptor species
- Identify sensitive receptors, if any
- Make observations regarding ecosystem health
- Provide a future basis for evaluation of remedial alternatives, if necessary.

The habitat characterization activities will include:

- Preparation of a cover-type map to identify habitat type, as well as current and past land uses that have influenced habitat development at the site
- Correspondence with agencies and review of Natural Heritage Inventory data, FWS and Montana Fish, Wildlife, and Parks records, National Wetland Inventory (NWI) maps, and other sources of ecological information
- Development of a list of resident fish and wildlife species based on cover types present, agency records, and the distribution and habitat preferences of species as described in the literature
- Field reconnaissance to finalize the cover-type map, classify natural communities, and assess habitat features of importance to wildlife in each major cover type
- Preparation of a list of plant species by visually estimating percent cover by species along transects in each major vegetated cover type
- Identification of fish, birds, mammals, and other wildlife using the site, based on direct observations and wildlife signs, such as tracks, scat, nests, and dens.

5.2 Selection of Reference Sites

The measures of exposure and effect will be compared statistically to data from control or reference site(s) for each distinct exposure area (i.e., Prickly Pear Creek, Lower Lake, Upper Lake, Upper Lake Marsh, upland areas). According to EPA guidance, "The development of exposure-response relationships is critical for evaluating risk management options; thus… sampling is applied to a contamination gradient when possible as well as compared to reference data. Reference data are baseline values or characteristics that should represent the site in the absence of contaminants released from the site" (U.S. EPA 1997) . Because there are no data from the site that were collected before contamination occurred, new data from reference sites will be collected as part of Phase I field studies.

It is usually not possible to find a perfect reference location that exactly matches the physical, climatic, chemical, and biological aspects of a site, because natural environmental characteristics vary widely, even among similar habitats (U.S. EPA 1994). In the supplemental ERA, EPA (2005b) selected a location in Prickly Pear Creek, upstream of the site, as the creek reference site (refer to Figure 3), and several ponds along the edge of Canyon Ferry Reservoir as the reference site for Lower Lake and Upper Lake. These sites will be visited during the 2009 field work and evaluated as potential reference locations.

A minimum of five data points are necessary to make valid statistical comparisons between the site and the reference site. Therefore, in the Phase I field study, five samples will be collected from Prickly Pear Creek upstream of the site to represent reference conditions for the creek. These sample locations will be identified in the field, and their selection will consider physical characteristics such as stream width, depth, flow, substrate type, and riparian habitat characteristics that are similar to the downstream (or site) locations. The ponds at Canyon Ferry Reservoir will be visited in the field and assessed as potential reference locations for Upper and Lower Lakes. If these sites are not found to be physically and biologically similar to Upper and Lower Lakes, other local water bodies will be researched as potential reference sites. In selecting the aquatic reference sites, physical data (including water temperature, depth, width, flow; sediment TOC, AVS, grain size, bottom structure; and biological characteristics, including bank cover type and qualitative data on species diversity and abundance) will be collected and used to document and compare reference sites' similarity to the site habitats.

No upland reference site was assessed in the Supplemental ERA. In the Phase I study, the reference site used in the 1987 RI of soils, vegetation, and livestock (C2M Hill 1987a), located 27 miles southeast of the site, will be evaluated for use as the upland reference site to represent local background. Soil characteristics, including soil type, moisture content, particle size distribution, organic matter content, hydrologic regime, and pH, as well as vegetation cover types, will be assessed to match the reference site to the upland sampling locations at the site. Surrounding land uses will also be considered in reference-site selection. Similarly, local wetlands will be visited and compared to Upper Lake Marsh using similar characteristics, as well as qualitative data on species diversity and abundance, to select a marsh reference site.

As with Prickly Pear Creek, it is planned that five samples will be collected from each reference location for statistical comparison with site data collected from Upper and Lower Lakes, Upper Lake Marsh, and the onsite uplands. Reference-site locations, once determined, will be documented in the field using GPS. In addition, in accordance with our Application for Scientific Collector's Permit (Appendix B), Montana Fish, Wildlife & Parks will be notified of the location of the reference sites after appropriate sites are selected.

5.3 Aquatic Investigation

Based on previous work performed at the site, metals concentrations are elevated in several bodies of water on, adjacent to, or otherwise influenced by the site. These include Prickly Pear Creek, Upper Lake, Lower Lake, Upper Lake Marsh, and Wilson Ditch. Aquatic reference sites, including Prickly Pear Creek upstream of the site, a lake reference site, and a marsh reference site, will also be sampled as described above. The lake and marsh reference sites, as well as the location of the upstream samples in Prickly Pear Creek, will be determined in the field (refer to Section 5.2, above).

Sediment, surface water, benthic invertebrates, fish, plants and algae, amphibians, and other aquatic prey species (e.g., snails, mussels, crayfish; dependent on availability) will be sampled to characterize metals in these aquatic systems. These samples will include site characterization samples (i.e., abiotic media, including soil, water, and sediment), and biota samples as follows:

- Surface water for chemical analysis
- Sediment for chemical analysis

- Fish, invertebrate, amphibian, and plant tissues for chemical analysis
- Sediment for toxicity testing.

Table 9 provides a summary of the site characterization samples that will be collected. Table 10 summarizes the biota samples. An Application for Scientific Collector's Permit (Appendix B) has been submitted to Montana Fish, Wildlife & Parks for the biota samples. Approximate aquatic sample locations are shown in Figure 7 for Prickly Pear Creek and Wilson Ditch, and Figure 8 for Upper/Lower Lakes and Upper Lake Marsh. Actual sample stations will be recorded in the field using GPS. Reference-site locations will be determined and similarly recorded in the field.

Details on laboratory analytical methods for sediment, surface-water, and aquatic biota samples, and the numbers and types of samples to be taken for Quality Assurance (QA) (e.g., matrix spike, matrix spike duplicate, field blank, field duplicate) are provided in the FSAP (Appendix A). Additional information on sample numbering, field data forms, shipping, and chain-of-custody procedures is also provided in the FSAP.

5.3.1 Sediment Sampling

Sediment data are required for the characterization of exposure and effects of metals for benthic invertebrates, fish, and wetland plants, and for use in the wildlife food-chain models. The surface interval for bottom sediments is where bioturbation and mixing occur, and the exposure potential is highest for ecological receptors. Therefore, sediment samples will be collected from the 0- to 6-inch interval. This sampling depth is consistent with prior sediment sampling at the site, and with the risk assessment data needs. Table 9 summarizes the site characterization samples that will be used for estimating sediment exposures in the BERA, and the sediment sampling locations are shown on Figures 7 and 8. Twenty-seven sediment samples will be collected from the site, and 15 samples will be collected from reference sites. The sediment sampling locations are described as follows:

- Five stations in Prickly Pear Creek adjacent to and downstream of the site
- Five stations in Upper Lake

- Five stations in Lower Lake
- Nine stations within the portion of the Upper Lake Marsh that is subject to periodic flooding
- Three stations in Wilson Ditch
- Five reference stations in Prickly Pear Creek upstream of the site
- Five stations from the lake reference site
- Five stations from the marsh reference site.

Each sediment sample will be a composite of five grab samples collected at each sampling station, with all samples collected from the 0- to 6-inch depth interval. The stream sediment samples will be collected from the streambed in apparent depositional zones (slack current).

Surficial sediment samples will be taken from the top 6 inches of sediment, or less if the sediment layer is thinner than 6 inches. A grab-type sampling device will be used. Depending on water depth and sediment grain size, either a petite Ponar, tall Ekman, or hand auger will be used for sediment sampling, as determined in the field. A coring device may be used, if necessary, for deeper sediment samples (e.g., in Lower Lake and Upper Lake). Methods for using these devices are described in the FSAP (Appendix A) and Standard Operating Procedures (SOPs) that are provided as part of the FSAP. AVS/SEM samples will be collected directly from the grab. This will reduce disturbance to the sediment, which could potentially result in the loss of volatile materials. Once a grab sample is collected, the sediment will be placed in a stainless-steel bowl and homogenized with a stainless-steel spoon. Because multiple grab samples are being collected from each location, the grab sampler will be moved slightly laterally to avoid sampling the same spot. Unrepresentative material, such as stones or wood chips, will be removed from the bowl during compositing. Subsamples of the homogenized sediment will be taken from the bowl and placed into appropriate sample containers for chemical analysis (and sediment toxicity testing as described in Section 5.3.7).

Sample containers for chemical analysis will be placed on ice immediately after collection and maintained at a temperature of approximately 4 °C in coolers during transport to the receiving laboratories. Information on collection containers, sample numbering, holding times, chain of custody (COC), and shipping procedures is provided in the FSAP (Appendix A).

The sediment sample analytical parameter list is provided in Table 11. Sediment samples will be analyzed for the 19 metals identified in the expanded parameter list for the Phase II RFI. Sediment will also be analyzed for AVS/SEM, particle size distribution, moisture content, pH, and TOC. A subset of sediment samples (approximately one-third of the samples) will also be analyzed for methyl mercury. Sediment analytical data will be reported in milligrams per kilograms, dry weight. Detailed information on analytical methods is also provided in the FSAP (Appendix A).

5.3.2 Surface-Water Sampling

Surface-water data are required for the characterization of exposure and effects of metals for fish and wetland plants, and for use in the food-chain models for wildlife receptors. Although ingestion of surface water is a minor pathway for wildlife, water ingestion is a parameter that is included in the food-chain models. Surface-water samples will be collected at the same locations as the sediment samples: five stations in Prickly Pear Creek adjacent to and downstream of the site, five stations on Upper Lake and Lower Lake, nine stations in Upper Lake Marsh, at three locations in Wilson Ditch, and at the reference sites. These samples are in addition to the semiannual water quality sampling of Prickly Pear Creek that will occur in summer and fall 2009 under Asarco's ongoing Comprehensive RI/FS surface-water monitoring program. The monitoring data will also be evaluated for use in the BERA. Surface-water sampling stations are shown in Figures 7 and 8, and the samples are summarized in Table 9. As with sediment, 23 surface-water samples will be collected from the site, and 15 samples will be collected from reference sites.

Surface-water sampling will occur after the high streamflow period, most likely in late July or August. Surface-water sampling will include collection of water samples for laboratory analyses, and field measurement of pH, specific conductance, dissolved oxygen, temperature, depth, and flow velocity. The surface-water analytical parameter list is provided in Table 12. Surface-water samples will be analyzed for the 19 metals identified in the expanded parameter list for the Phase II RFI. Both total recoverable and dissolved metals will be measured. A subset of surface-water samples (approximately one-third of the samples) will also be analyzed for methyl mercury. Surface water will also be analyzed for major ions and physical parameters as listed in Table 12, and hardness will be calculated from these data. Surface-water chemistry data will be reported in micrograms per liter (µg/L), or parts per billion (ppb). Detailed information on analytical methods is provided in the FSAP (Appendix A).

The surface-water sampling in Prickly Pear Creek will occur in a synoptic fashion, with sample collection and streamflow measurements to occur in a downstream-to-upstream direction to minimize the influence of sediment disturbance on downstream samples, and to complete sample collection in as short a timeframe as possible. The resulting data will provide a "snapshot" of streamflow and metals loading trends along each stream segment.

Surface-water samples will be collected just below the water surface by immersing the sample container and allowing it to fill. If deeper water is to be sampled, a decontaminated dipper or grab-type sampling device will be used. Water quality parameters (temperature, dissolved oxygen, pH, turbidity, and conductivity) will be measured using a multi-meter probe, which will be calibrated daily. Flow velocity will be measured using a flow meter and depth rod. Detailed methods for collecting surface-water samples and using these devices are described in the FSAP (Appendix A) and in the SOPs provided in the FSAP.

5.3.3 Benthic Invertebrate Sampling

Benthic invertebrates are an important receptor at the site, because they are relatively immobile and have the greatest potential exposure to metals in sediment, and they provide food for fish, mammals, and birds. Benthic invertebrate tissue chemistry will be used to characterize exposure of fish and wildlife receptors (refer to Table 10). Benthic invertebrates will be sampled from approximately the same stations as surface water and sediment in Prickly Pear

Creek, Upper Lake, Lower Lake, Upper Lake Marsh, and possibly Wilson Ditch[9] if found to be present, as well as from the reference sites. Composite samples of benthic invertebrates will be collected from each sampling location to achieve the minimum mass required for chemical analysis (10 g). If present at all locations, a maximum of 25 benthic invertebrate samples will be collected from the site for chemical analysis, and 15 samples will be collected from reference areas (Table 10). Target invertebrates for sampling include aquatic insect early life stages and aquatic worms. Crayfish, mussels, and snails are also benthic invertebrates, and may be sampled if present; however, these prey items are discussed under "other aquatic prey" (refer to Section 5.3.5). A variety of collection methods can be used to collect benthic invertebrates: picking by hand, using various types of nets, or setting traps. Specific details on the methods that may be used are provided in the FSAP and SOPs (Appendix A).

The analytical parameter list for biota samples is provided in Table 13. Biota samples, including benthic invertebrates, will be analyzed for the 19 metals identified in the expanded parameter list for the Phase II RFI, and moisture content will also be measured. A subset of benthic invertebrate samples (approximately one-third of the samples) will also be analyzed for methyl mercury. Detailed information on analytical methods is also provided in the FSAP (Appendix A). Benthic invertebrate chemistry data, will be reported in milligrams per kilograms, wet weight, as will all biota samples.

5.3.4 Fish Sampling

Fish samples are summarized in Table 10. Forage-fish tissue samples will be used in the food-chain models to characterize wildlife exposure, and will also be used to characterize dietary exposure for larger, predatory fish. Piscivorous, or predatory, fish of a larger size class will also be sampled to characterize exposure and effects in the fish themselves, and also for wildlife receptors that may use larger fish as a component of their diet (e.g., as in the case of mink). Finally, game fish will also be collected and filleted for use in the human health risk assessment. The species targeted for sampling will be those that may potentially serve as a food resource for piscivorous birds and mammals, and also game species commonly consumed by humans.

[9] Note that biota samples will be collected only in Wilson Ditch as part of the Phase II ecological investigation; if risks cannot be concluded to be negligible in Phase I (refer to Section 7.2).

Because data are not available on the fish community composition at the site and reference areas, a reconnaissance survey will be conducted to provide data for selection of target species for the investigation.

Fish will be sampled from approximately the same stations as surface water and sediment in Prickly Pear Creek, Upper Lake, Upper Lake Marsh, and possibly Lower Lake if found to be present, as well as from the reference sites (Table 10). Composite samples of fish will be collected, if necessary, from each sampling location to achieve the minimum mass required for chemical analysis (10 g). If present at all locations in the Phase I field study, a maximum of 25 forage-fish samples will be collected from the site for chemical analysis, and 15 forage-fish samples will be collected from reference areas. Larger size-class fish are not expected in Lower Lake, Upper Lake Marsh, and Wilson Ditch. Therefore, it is expected that ten predatory fish samples will be collected from the site: five from Prickly Pear Creek and five from Upper Lake. Ten predatory fish will also be sampled from the representative reference areas. Similarly, five fillet samples will be collected from Prickly Pear Creek and Upper Lake, for a total of ten fillet samples.

Fish may be collected by several methods, including electrofishing, seining, gill netting, angling, and trapping. Specific sampling protocols for each of these methods are provided in the FSAP and associated SOPs (Appendix A). Fish samples will be identified to the lowest practical taxonomic level, and lengths and weights will be measured for non-forage species. Target species will be collected to estimate exposure in humans, belted kingfisher, mink, and predatory fish. Results of previous fish sampling conducted at the site and reference locations provide a list of likely species that can be expected to be encountered during this sampling effort. For human exposure, expected target species include rainbow trout and brook trout. Fish analyzed for human exposure will be filleted, and only the fillet (e.g., muscle tissue) will be analyzed. Expected forage fish, which will be used to estimate exposure in kingfisher and mink, will consist of any small species encountered and sampled, such as minnows and shiners. Larger predatory, or piscivorous, fish will also be sampled to directly measure fish exposure. Although no truly piscivorous species have been noted in previous studies, both species of trout are predators but feed on invertebrates as well as other fish. White sucker and sculpin, both bottom-dwelling species, are also known to inhabit some of the waters associated with the site. These species may be sampled if other target species are not encountered.

The analytical parameter list for biota samples is provided in Table 13. Detailed information on analytical methods is also provided in the FSAP (Appendix A). Analytical results for fish will be reported in mg/kg, wet weight.

5.3.5 Sampling of Other Aquatic Biota

Crayfish, mussels, and snails are also important prey items for wildlife receptors, and will be sampled to the extent they are available. Table 10 provides an estimate of 25 total samples of "other aquatic prey," with five composite samples collected from each of the onsite aquatic environments (i.e., Prickly Pear Creek, Lower Lake, Upper Lake, and Upper Lake Marsh). A total of 15 samples of other aquatic prey items would also be collected from the creek, lake, and marsh reference sites. Actual organisms and numbers of samples that will be collected of these prey items will be based on the prevalence of species found in each habitat. Refer to Section 5.3.3 for an overview of the methods that will be used to collect other aquatic biota.

Amphibians may also be collected, because they are components of the mink and belted kingfisher diets. Some methods that are typically used to collect fish and larger benthic invertebrates (e.g., crayfish) are effective for sampling amphibians. Dip netting and seining from shore will likely be the most effective methods of sampling. Specific sampling protocols are provided in the FSAP and SOPs (Appendix A). The analytical mass requirement for each amphibian and other prey item sample (10 g) will be achieved by collecting composite samples where necessary.

Analyses for these samples will be the same as for benthic invertebrates, described in Section 5.3.3. above, and results will be reported in mg/kg, wet weight.

5.3.6 Aquatic Plant and Algae Sampling

Aquatic vegetation and algae samples will be collected to investigate the potential for trophic transfer of metals via the food chain to wildlife receptors, such as the mallard duck. Table 10 provides an estimate of 25 total site samples of aquatic plants and algae, with five composite samples collected from each of the onsite aquatic environments (i.e., Prickly Pear Creek, Lower Lake, Upper Lake, and Upper Lake Marsh). A total of 15 samples plants/algae will also be collected from the creek, lake, and marsh reference sites.

Target plant species will be identified in the field based on dominance and importance in the food chain. Aquatic macrophytes and algae will be collected by hand by wading, by boat, and/or from shore. For macrophytes, the entire plant will be sampled, with care taken to remove most, if not all, of the tissue from the substrate. Algae samples will be collected by plankton net, or by scraping a known surface area substrate clean of algal material, or setting out artificial substrates and allowing them to sit for a specified period of time to allow algal growth. Specific sampling protocols are described in the FSAP and associated SOPs (Appendix A). Target species will be selected in the field based on abundance. The analytical mass requirement for each sample is a minimum of 10 grams. Plant and algae samples will be stored on ice for shipment via overnight courier to the analytical laboratory.

The analytical parameter list for biota samples is provided in Table 13. A subset of plant tissue and algae samples (approximately one-third of the samples) will also be analyzed for methyl mercury. Detailed information on analytical methods is also provided in the FSAP (Appendix A). Analytical methods for plant tissue and algae analyses, and samples to be taken for QA purposes (e.g., matrix spikes), are described in the FSAP (Appendix A). All aquatic plant and algae tissue data will be reported in mg/kg, wet weight.

5.3.7 Sediment Toxicity Testing

Prickly Pear Creek is the subject area of the proposed sediment toxicity study. Metals were found to be the principal CoPCs, and therefore, sediment samples for toxicity testing will be selected based on the metal concentrations observed during previous sampling. Sediment sampling locations for toxicity testing will be selected based on previous data, for the purpose of obtaining samples that span the range of metal concentrations present in sediments in the Prickly Pear Creek adjacent to the site. Ten sediment samples will be collected from areas adjacent to and downstream of the site, and five sediment samples will also be collected from upstream reference locations. Specific sediment locations will be located in the field and documented using GPS. All sediment samples will be chemically characterized to verify that a range of metal concentrations are achieved prior to conducting the bioassays. Following metals screening, the sediment samples will be tested. Whole sediment toxicity to benthic invertebrates will be assessed using a standard sediment toxicity test conducted in the laboratory. The selection of a toxicity test is described in detail below. Toxicity of site sediments will be compared to that of reference-site sediments to assess the potential for adverse effects to benthic invertebrates resulting from site sediments. Interpretation of the results from the toxicity tests will also include consideration of non-contaminant-related factors (e.g., sediment grain size, pH, and TOC).

5.3.7.1 Sediment Sampling for Toxicity Testing

Sediment samples will be collected from 0–6 in. depth. Samples of sediment will be collected using an Ekman dredge if overlying water is present, or by trowel, hand auger, or hand corer if the area to be sampled is dry. Sampling equipment will be decontaminated prior to use and between sampling stations. A minimum of four liters of sediment will be collected from each location to ensure sufficient sample volume for chemical analysis and toxicity testing. Multiple grab samples will be taken from each location to obtain sufficient sample volume. The sampler will be moved slightly laterally to avoid sampling the same spot. Sediment from the desired depth horizon will be transferred to a stainless-steel bowl and homogenized. Unrepresentative material (e.g., stones, wood chips) will be removed from the stainless-steel bowl at the discretion of the field supervisor and will be noted in the field notebook. Subsamples of the homogenized sediment will be taken from the stainless-steel bowls and placed into appropriate sample containers. Sample containers for chemical analysis and toxicity testing will be placed on ice immediately after collection and maintained at about 4 °C in coolers during transport to the receiving laboratories.

5.3.7.2 Toxicity Testing Methods

Sediment toxicity tests will be used to directly measure the potential bioavailability and toxicity of sediments in Prickly Pear Creek to benthic invertebrates. The choice of a test organism and protocol has a major influence on the relevance, success, and interpretation of a study. The scientific literature demonstrates that no single organism is best suited for all sediments (ASTM 2007). Therefore, we will conduct two standard toxicity tests using two freshwater organisms. The first test is the 28-day whole-sediment toxicity test with *Hyalella azteca*. This test is used to estimate the chronic toxicity of whole-sediment samples, and endpoints measured include survival and growth (dry weight) on day 28. This procedure is a modification of the U.S. EPA (2000) guidelines, Method 100.4. In this modification, the test duration is shortened from 42 days to 28 days by excluding the water-only phase exposure (Days 28–42) outlined in Method 100.4, and the reproduction endpoint is not determined. The 42-day test, which is commercially available, includes an assessment of the reproductive endpoint. However, it has been shown that the reproductive response assessed in the 42-day test is often more variable than the survival and growth response and, as a result, less sensitive. The second test is the 28-day whole-sediment toxicity test with *Chironomus dilutus* (formerly *Chironomus tentans*). This test is used to estimate the toxicity of whole-sediment samples to the freshwater midge, *C. dilutus*. Endpoints measured include survival and growth (dry weight) on day 28. This procedure is based on the U.S. EPA (2000) guidelines, Method 100.2.

The holding time for the sediment for use in toxicity tests is not to exceed two weeks. A quality control toxicity test is not used. Both the laboratory control and background samples will provide information on the quality of the tests.

5.4 Terrestrial Investigation

Upper Lake Marsh, the banks of Upper and Lower Lakes, the Prickly Pear Creek riparian zone, and the onsite and perimeter upland areas are potential terrestrial habitat for soil invertebrates, plants, and wildlife. Surface soil and soil invertebrates, including earthworms, will be collected for metals analysis, to investigate the potential for trophic transfer of site CoPCs via the food chain to higher-trophic-level wildlife receptors, such as songbirds and small mammals. These samples will include site characterization samples (i.e., abiotic media, including soil, water, and sediment), and biota samples as follows:

- Surface soil for chemical analysis
- Soil invertebrate, including earthworms, for chemical analysis.

Table 9 provides a summary of the site characterization samples that will be collected. Table 10 summarizes the biota samples. Approximate upland sample locations are shown in Figure 4 (site and perimeter samples) and Figure 8 (bank soil stations for Lower and Upper Lakes, and Prickly Pear Creek riparian zone). Actual sample stations will be recorded in the field using GPS. An upland reference site location will be determined and similarly recorded in the field.

Details on laboratory analytical methods for surface soil and terrestrial biota samples, and the numbers and types of samples to be taken for QA purposes (e.g., matrix spike, matrix spike duplicate, field blank, field duplicate) are provided in the FSAP (Appendix A). Additional information on sample numbering, field data forms, shipping, and chain-of-custody procedures is also provided in the FSAP.

5.4.1 Surface-Soil Sampling

The locations of the existing surface-soil samples for the terrestrial habitats in these areas are shown in Figure 4, and the historical data are provided in Table 5. Site characterization samples of surface soil (and/or sediment in the case of Upper Lake Marsh[10]) will be used to develop exposure estimates for terrestrial receptors. Composite surface-soil samples will be collected from the following locations, as well as the upland reference site (Table 9):

- Four stations from the banks of Lower Lake
- Four stations from the banks of Upper Lake
- Six stations from the site perimeter
- Five stations in the area between Upper and Lower Lakes (also called "Tito Park")
- Five stations along the riparian zone of Prickly Pear Creek
- Four stations within the Lower Ore Storage Area onsite
- Three stations within the Rail Car Staging Area onsite
- Four stations from miscellaneous unpaved areas onsite.

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[10] Upper Lake sediment samples are discussed in Section 5.3.1.

For the Phase I BERA field investigation, 30 samples of soil will be collected on the site from the 0- to 6-inch interval and analyzed for metals, particle size distribution, moisture content, pH, and TOC, to assess potential risk to ecological receptors. Five soil samples will be collected from the upland reference site (location to be determined in the field). The proposed soil sampling locations are shown on Figure 4 for the onsite/facility perimeter sampling stations, and Figure 8 for the Lower/Upper Lake, and Prickly Pear Creek bank sample stations. The soil-sample analytical parameter list is provided in the same table as for sediment, Table 11.
A subset of soil samples (approximately one-third of the samples) will also be analyzed for methyl mercury. Soil analytical data will be reported in mg/kg, dry weight. Detailed information on analytical methods is provided in the FSAP (Appendix A).

5.4.2 Terrestrial Invertebrate Sampling

Soil invertebrates (e.g., sow bugs, spiders, beetles), and specifically earthworms, will be collected, where available, to investigate the potential for food-chain transfer of metals to higher-trophic-level wildlife receptors; in this case, songbirds. Table 10 summarizes the terrestrial invertebrate samples that will be collected. Composite terrestrial invertebrates samples will be collected as follows, for a total of 14 site samples and five reference samples:

- Two samples from the banks of Lower Lake
- Two samples from the banks of Upper Lake
- Two samples from the area between Upper and Lower Lakes
- Five samples total from theonsite uplands, including the site perimeter
- Three samples from the Prickly Pear Creek riparian zone
- Five samples from the upland reference site (location to be determined).

Composite earthworm samples will also be collected, for a total of 17 site samples and 10 reference samples:

- Two samples from the banks of Lower Lake
- Two samples from the banks of Upper Lake
- Two samples from the area between Upper and Lower Lakes
- Five samples total from the onsite uplands including the site perimeter
- Three samples from the Prickly Pear Creek riparian zone
- Three samples from Upper Lake Marsh
- Five samples from the upland reference site
- Five samples from the marsh reference site (reference site locations to be determined in the field).

Upland sampling locations are shown on Figure 4 and Figure 8 for the Lower/Upper Lake and Prickly Pear Creek bank sample stations. Biota samples will be collected at a subset of sampling stations, to be determined in the field.

Specific sampling protocols for terrestrial invertebrates are described in the FSAP and associated SOPs (Appendix A). Soil invertebrate samples will be rinsed in distilled water, placed in jars, and kept in a cool, dark environment until they are depurated (the digestive tract is evacuated). After depuration, the samples will be placed in pre-cleaned jars and stored on ice for overnight courier shipment to the analytical laboratory. The actual sample weight will be determined based on the weight of the invertebrates collected at each sampling station and on the minimum sample weight required by the laboratory to perform all analyses to the required reporting limit (10 g).

The analytical parameter list for biota samples is provided in Table 13. A subset of terrestrial invertebrate and earthworm samples (approximately one-third of the samples) will also be analyzed for methyl mercury. Detailed information on analytical methods is also provided in the FSAP (Appendix A). Analytical methods for tissue analyses, and samples to be taken for

QA purposes (e.g., matrix spikes), are described in the FSAP (Appendix A). All soil invertebrate tissue data will be reported in mg/kg, wet weight.

5.5 Investigation of Groundwater/Surface-Water Interactions

As reported previously (Hydrometrics 1999; ACI 2005), groundwater recharge to Prickly Pear Creek is believed to occur in the vicinity of Lower Lake. Based on the elevated groundwater arsenic concentrations in this area, the potential groundwater recharge could represent a source of metals loading to the creek. Seepage of metals-bearing groundwater to the creek could also affect aquatic biota within the groundwater/surface-water transition, or hyporheic zone. As part of the Phase I ecological studies, a detailed evaluation of the groundwater/surface-water interaction will be conducted in the area between Lower Lake and Prickly Pear Creek to assess any effects of metals-bearing groundwater on the quality of surface water within the creek and water within the underlying hyporheic zone. Objectives of this investigation include:

1. Accurately define groundwater flow directions, flow rates, and water quality in the area between Lower Lake and Prickly Pear Creek
2. Provide a detailed assessment of groundwater/surface-water interaction between Lower Lake, the intervening groundwater system, and Prickly Pear Creek
3. Document within Prickly Pear Creek surface-water quality and hyporheic zone water quality, and determine to what extent groundwater recharge to the creek influences water quality within the riverine system.

The investigation of groundwater/surface-water interactions in the vicinity of Lower Lake is one component of a similar site-wide investigation planned by Asarco for 2009 as part of the Phase II RFI supplemental site characterization program. In order to focus the investigation on the interrelationship between Lower Lake, Prickly Pear Creek, and the intervening groundwater system, the investigation will concentrate on the movement and geochemical evolution of groundwater along three potential flow paths between the lake and creek. The theoretical flow paths are closely aligned with the expected general groundwater flow direction in this area, and have been located to incorporate existing monitoring wells DH-4, APSD-7, and APSD-8 into the study (Figure 9). For each flow path, monitoring and testing will be conducted at the upstream end (Lower Lake), the downstream end (Prickly Pear Creek), and multiple groundwater monitoring points in between (including the hyporheic zone). The various flowpaths, monitoring points, and proposed sampling/testing are summarized in Table 14 and described below.

5.5.1 Flow Paths

Flow Path 1, as shown on Figure 9, represents the downgradient area where metal-bearing groundwater has the potential to be discharged to the creek and hyporheic zone. This flow path encompasses existing monitoring locations Lower Lake, monitoring well DH-4, and Prickly Pear Monitoring Site PPC-5. In addition, two piezometers (PZ-1 and PZ-2) and an interstitial monitoring point (IST-1) will be installed in the lowland area between DH-4 and PPC-5. These monitoring points will evaluate the evolution of groundwater as it flows from Lower Lake through the groundwater system (DH-4, PZ-1, and PZ-2), and the potential for the groundwater to move through the hyporheic zone (IST-1) before it discharges to Prickly Pear Creek at PPC-5.

An additional piezometer (PZ-3) will be installed on the eastern bank of Prickly Pear Creek, in the vicinity of Flow Path 1, to evaluate the influence of groundwater from the east on surface water and the underlying hyporheic zone.

A second flow path (Flow Path 2) is located in conjunction with monitoring well APSD-7 and PPC-103, where small increases in arsenic concentrations have been historically observed in Prickly Pear Creek. Installation of one additional piezometer (PZ-04) in the lowland area between APSD-7 and the creek, and one interstitial monitoring point (IST-2 underlying the creek at PPC-103) is proposed for this flow path.

The third flow path represents the upgradient area where metal-bearing groundwater has the potential to be discharged to Prickly Pear Creek and encompasses existing monitoring points in Lower Lake, APSD-8, and PPC-102. As with Flow Path 2, one additional piezometer (PZ-5) and one interstitial monitoring point (IST-3) will be installed to evaluate the geochemical evolution of metal-bearing water as it flows from Lower Lake, through the groundwater (APSD-8 and PZ-5), through the hyporheic zone (IST-3), and where it is potentially discharged to Prickly Pear Creek (PPC-102).

5.5.2 Piezometer/Interstitial Monitoring Point Installation

The piezometers will be installed with a direct-push drill rig or backhoe, depending on site access. The total depth of the piezometers is anticipated to be approximately 10 ft, but total depths may vary depending on site conditions. Each piezometer will be installed with a five-foot screen and will be constructed in accordance with State of Montana regulations (ARM 36.21.800). A qualified scientist or engineer will supervise the installation of all piezometers and interstitial monitoring points, and will provide detailed lithologic and construction details for each point.

The interstitial monitoring points (mini-piezometer) will be installed in a manner to evaluate the potentiometric head and water quality in the hyporheic zone. The monitoring points will be installed by hand to a depth of approximately 1 ft beneath the top of the streambed. The monitoring points will either be open-ended or will have a screened/perforated zone not to exceed 4 inches that will allow for discrete monitoring of the hyporheic zone.

5.5.3 Monitoring and Testing Program

The monitoring program will consist of collection of groundwater, hyporheic zone, and surface-water elevation data, streamflow monitoring in Prickly Pear Creek, and water quality sampling in Lower Lake, Prickly Pear Creek, and the intervening groundwater and hyporheic system. Below is a summary of the monitoring programs associated with the groundwater/surface-water interaction study in the vicinity of Lower Lake.

Water elevation data will be collected weekly for a month, from monitoring points associated with the three flow paths, and in conjunction with any additional monitoring conducted as part of the groundwater/surface-water interaction study. In addition, surface-water flow measurements and water quality samples will be collected from each monitoring point within

2 weeks following installation of the flow-path monitoring points, and 1 to 2 months later to verify the initial monitoring results. Long-term monitoring will be conducted in accordance with the site-wide investigation of the groundwater and surface-water interaction that will be included in the Phase II RFI supplemental site characterization program. The two monitoring events will include field testing for pH, specific conductance, dissolved oxygen, water temperature and static water level, and laboratory analysis of dissolved and total recoverable (groundwater dissolved only), common ions, and general chemistry (Table 12).

Hydrologic conditions such as hydraulic conductivities, groundwater flux, and streambed conductance will be evaluated by conducting slug tests, and/or grain size analyses on each piezometer and interstitial monitoring point in accordance with procedures and techniques defined in the EPA-approved *Interim Measures Work Plan, East Helena Facility* (Hydrometrics 1999b), and the *RCRA Facility Investigation* Work Plan (Hydrometrics 2000).

5.6 Statistical Evaluation

Statistical analyses will be conducted to determine which samples from the site, if any, are statistically different from the laboratory control (in the case of Prickly Pear Creek sediment toxicity testing) and reference-site samples. The statistical analyses used for this study will follow EPA guidance on statistical methods (U.S. EPA 2006). The significance level (i.e., alpha level) of the statistical tests will be set to 0.05. The software program S-Plus® (Insightful) or similar statistical software will be used to analyze the data.

To determine which statistical tests to use, the data will be tested for equal variance and normality. The Levene's test will be used to determine whether the data for the groups being compared exhibit equal variance. The Levene's test was selected because it is a robust assessment of the variance regardless of the underlying distribution of the data (U.S. EPA 2006). The Shapiro-Wilkes test and probability plots will be used to determine whether the data are normally distributed. Data that have unequal variance or lack normality will be mathematically transformed, and re-tested in accordance with the above methods.

If the data have equal variance and are normally distributed, parametric tests will be used. Parametric tests are the most statistically powerful methods for detecting a difference when the assumptions of normality and equal variance are met. Below are the steps of the parametric statistical analysis.

1. Perform an ANOVA[11] followed by Dunnett's[12] post-hoc multiple comparison test (alpha = 0.05) for differences between toxicity test samples from site locations and the laboratory control.

2. Perform an ANOVA followed by Dunnett's post-hoc multiple comparison test (alpha = 0.05) for differences between samples from reference-site locations and the laboratory control.

3. Perform an ANOVA to test for differences among site and reference-site samples. Compare each site sample against the reference-site samples considered as a group using a test of contrast. The significance level for each test will be adjusted to achieve the 0.05 significance level across all tests conducted.

If the data do not have equal variance and are not normally distributed, non-parametric tests will be used. Below are the steps of the non-parametric statistical analysis.

1. Perform a Kruskal-Wallis followed by Wilcoxon tests (overall alpha = 0.05) for differences between toxicity test samples from site locations and the laboratory control.

2. Perform a Kruskal-Wallis followed by Wilcoxon tests (overall alpha = 0.05) for differences between samples from reference-site locations and the laboratory control.

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[11] Analysis of variance

[12] Dunnett's test is most powerful for comparing multiple groups against a single group, such as a laboratory control.

3. Perform a Kruskal-Wallis to test for differences among site and reference-site samples. Compare each site sample against the reference-site samples considered as a group using a Wilcoxon test. The significance level for each test will be adjusted for the number of tests conducted in order to maintain the significance level of 0.05 used for this study.

If the data have equal variance but are not normally distributed, both parametric tests and non-parametric tests described above will be conducted to determine which of the site samples are statistically different, if any, from the laboratory control and reference site samples. This approach will ensure that any significant differences do not go undetected due to the lower statistical power of the non-parametric methods, and that potential bias due to the lack of normality does not affect interpretation of the parametric test results.

6 Baseline Ecological Risk Assessment

The purpose of the East Helena Smelter BERA is to estimate the magnitude of risks to ecological receptors posed by current or future exposure to metals in soil, water, sediments, and biota onsite and in areas adjacent to the site. The BERA will be designed to provide adequate information to support risk management decisions and determine whether corrective measures are needed to protect ecological resources.

The goal of the BERA is to evaluate whether exposures to CoPCs in terrestrial and aquatic environments at the Asarco facility site have the potential to result in adverse effects to ecological receptor populations. The BERA work plan and FSAP (Appendix A) were developed to guide Phase I data collection in the summer 2009 field season, and to present a methodology for quantifying and interpreting ecological risks.

The BERA will be conducted in accordance with U.S. EPA ecological risk assessment guidance (U.S. EPA 1997, 1998, 2005b). The BERA is designed to fill data gaps identified in the supplemental ERA (U.S. EPA 2005b), in the current review of the available site information, and in discussions with the involved agencies. Accordingly, the BERA will differ from the supplemental ERA in the following ways:

- Risk will be assessed for additional wildlife receptors, including terrestrial upland species
- Risk will be assessed for Wilson Ditch
- A habitat characterization will be conducted to evaluate use of the site by ecological receptors
- New surface soil, sediment, and surface-water data will be collected for the complete metals parameter list, with appropriate analytical detection limits for addressing ecological measurement endpoints

- Biota sampling will be conducted to measure metals in invertebrate, fish, and plant tissues (and possibly others, depending on organism availability)—these data will be used to quantify exposure to wildlife receptors
- Methyl mercury will be analyzed in environmental media and biota, in addition to total mercury, for use in food-chain modeling to assess risk to wildlife receptors
- Sediment toxicity testing will be conducted on samples from Prickly Pear Creek
- Exposures from groundwater-to-surface-water discharge will be evaluated to address the potential influence of groundwater migration from Lower Lake to Prickly Pear Creek
- Food-chain modeling will be redone using more realistic, site-specific exposure parameters to more accurately address risk to wildlife.

6.1 Problem Formulation

The problem formulation for the BERA will draw upon the results of the screening assessment (Section 3.2) and the site-specific knowledge acquired through the Phase 1 ecological studies to refine the list of CoPCs and the preliminary CSM presented in Section 4. Verification of complete exposure pathways and habitat use by ecological receptors will be integrated into a final CSM. The assessment endpoints and measures of exposure and effects described in Sections 4.5 and 4.6 may be re-evaluated after the Phase I ecological field study if exposure pathways associated with the selected endpoints are determined to be incomplete, or data are incomplete to demonstrate a complete exposure pathway (U.S. EPA 1997). If data from the 2009 Phase I ecological study are found to be insufficient to assess certain exposure pathways, collection of additional field data may be proposed under the Phase II ecological investigation in 2010.

6.2 Exposure Assessment

For both terrestrial and aquatic communities, ecological receptors may be exposed to site-related CoPCs by various potential pathways. Primary exposure pathways are those expected to contribute the most to risk estimates, while secondary exposure pathways are not expected to increase risk substantially. Primary exposure pathways for terrestrial receptors include the consumption of plant material or prey and the incidental ingestion of sediment or soil. For plants, the primary pathways are the uptake of materials incorporated into soil. Primary exposure pathways for aquatic receptors (including aquatic wildlife) include the ingestion or uptake of surface water, consumption of contaminated plant material or prey, incidental ingestion of sediment during foraging, and direct contact with surface water. Exposure pathways for the site were described in Section 4.3.

U.S. EPA guidance (1997) suggests that, when characterizing exposures in the BERA, the ecological context of the site established during problem formulation be evaluated to gain a greater understanding of the potential effects of the ecosystem on the fate and transport of chemicals in the environment, and to evaluate site-specific characteristics of species or communities of concern. After the Phase I field study, any site-specific information that can be used to replace assumptions based on information from the literature or from other sites will be incorporated into the description of the ecological components of the site, to reduce the uncertainty associated with the exposure assessment.

The exposure assessment will include an analysis of the magnitude, duration, and frequency of exposure to CoPCs using data on:

- Chemical sources
- Chemical distributions in soil, water, sediment, plants, and prey
- Distributions of key ecological receptors (from the habitat characterization).

6.3 Exposure-Point Concentrations

An exposure-point concentration (EPC) is used to estimate the magnitude of exposure for each receptor that may contact metals in environmental media and plants/prey. EPCs are estimates of the average concentration in a medium that a receptor may be in contact with over time (U.S. EPA 1989). To account for uncertainty in estimating a true average concentration, EPA recommends calculating the 95% upper confidence limit (UCL) of the arithmetic mean concentration for each exposure area (U.S. EPA 1992, 2002). Typically, the lesser of the UCL or the maximum detected concentration is used as the EPC, whichever is lower. The 95% UCLs will be calculated in accordance with EPA guidance (Singh and Singh 2007; ProUCL 4.0. 2007) using EPA's software ProUCL 4.0. 95% UCLs will be calculated, where feasible, to represent average exposures; however, the BERA will also consider the range of exposure by calculating the arithmetic mean and maximum concentrations for each exposure area, to provide a range of exposure estimates over which to characterize risk. In calculating EPCs, one-half the detection limit will be used for all non-detects.

6.3.1 Wildlife Exposure Modeling

The primary routes of exposure for wildlife (mammals and birds) are expected to be through ingestion of food and water, and possibly incidental ingestion of soil and sediment (Sample et al. 1996). This section describes the food-chain model that will be used to evaluate risk to wildlife from exposure to CoPCs at the site.

To assess ecological risks to birds and mammals, food-web models will be structured to estimate site-specific daily doses of CoPCs to these receptors. This approach will allow for a direct comparison of exposure rates with measures of toxicity in the risk characterization. The ratio of an exposure estimate to an ecotoxicity value, such as a TRV, is known as a hazard quotient (U.S. EPA 1997).

The food-web modeling approach that will be used is a standard approach that is consistent with U.S. EPA's wildlife exposure guidance (U.S. EPA 1993; 61 Fed. Reg. 47552). The food-web model estimates dietary exposure as a body-weight-normalized total daily dose for each receptor species. The general structure of the food-web exposure model is described by the following equation:

$$IR_{chemical} = \frac{\sum_i (C_i \times M_i \times A_i \times F_i)}{W}$$

where:

$IR_{chemical}$= total ingestion rate of chemical from all dietary components (mg/kg body weight/day)

C_i = concentration of the chemical in a given dietary component or inert medium (mg/kg), the 95% UCL of the mean, the mean, and maximum C will be used

M_i = rate of ingestion of dietary component or inert medium (kg/day)

A_i = relative gastrointestinal absorption efficiency for the chemical in a given dietary component or inert medium (fraction)

F_i = fraction of the daily intake of a given dietary component or inert medium derived from the specific water body or location (unitless area-use factor)

W = body weight of receptor species (kg).

The term $IR_{chemical}$ can be expanded to specify each ingestion medium, which includes one or more primary food items, drinking water, and incidentally ingested sediment:

$$IR_{chemical} = [\Sigma\,(C_{food} \times M_{food} \times A_{food} \times F_{food}) + (C_{water} \times M_{water} \times A_{water} \times F_{water}) + (C_{sed} \times M_{sed} \times A_{sed} \times F_{sed})]/W$$

This model provides an estimated total dietary exposure for chemicals resulting from consumption of food, water, and the incidental ingestion of sediment on a mg/kg body-weight-day basis. For all receptors modeled, the exposure calculation conservatively assumes that 100% of the chemical in ingested food is absorbed ($A_i = 1$). $IR_{chemical}$ will be calculated using the 95% UCL of the mean, the mean, and the maximum concentration for C_i to provide a range of exposure estimates for each receptor.

6.3.1.1 Wildlife Receptor Profiles

Receptor profiles are developed for the following wildlife receptors for the BERA: belted kingfisher, mallard, tree swallow, American robin, mink, and short-tailed shrew. A receptor profile summarizes the parameters that are used to calculate an average daily dose of contaminants to a particular wildlife receptor. These parameters are body weight, normalized food ingestion rate, normalized sediment/soil ingestion rate, main dietary components, and foraging ranges for determining area use factors. If information for both sexes was available, profiles were based on the female. In general, females tend to be more sensitive to contaminants as a result of reproductive differences. The wildlife receptor exposure parameters are provided in Table 15.

The Wildlife Exposure Factors Handbook (U.S. EPA 1993) provides ranges of typical body weights and ingestion rates of food, as well as foraging areas for many wildlife species. Nagy (2001) provides more current estimates of food ingestion rates for wild animals. Beyer et al. (1994) and Beyer and Fries (2003) presented sediment/soil ingestion rates for selected wildlife. These sources were used to develop exposure factors for the wildlife receptors considered in this BERA. In some cases, the Wildlife Exposure Factor Handbook lists several values for a particular parameter. In those cases, the study from which the value was selected is noted in Table 15.

The estimates of food ingestion rates presented by Nagy (2001) were used for the wildlife receptors in this assessment (Table 15), and were derived for the wildlife receptors as follows:

- The food ingestion rate for the tree swallow was estimated using the dry ingestion rate equation for insectivorous birds (Nagy 2001).
- The food ingestion rate for the belted kingfisher is based on allometric equations for carnivorous birds (Nagy 2001).
- The food ingestion rates for the American robin and mallard were estimated using the dry ingestion rate equation for omnivorous birds in Nagy (2001).

- The food ingestion rate for the short-tailed shrew was estimated using the dry ingestion rate equations for insectivorous mammals in Nagy (2001).
- The food ingestion rate for the mink was estimated using the dry ingestion rate equation for the carnivorous mammals (Nagy 2001).

The dry-weight food ingestion rates were converted to wet-weight food ingestion rates by assuming a moisture content of animal matter of 80% (U.S. EPA 1993). Food ingestion rates were normalized to body weight.

The estimated percentage of soil/sediment in the diet of the wildlife receptors is provided for each receptor in Table 15. The percentage of soil/sediment in the diet of the mink was taken from Beyer et al. (1994). Beyer et al. (1994) do not present percentages of soil/sediment in diets of the American robin, belted kingfisher, or short-tailed shrew. The percentages of soil/sediment in diets of these species were based on percentages of soil/sediment in diets of other species with foraging strategies similar to these receptors. The percentage of soil in the diet of the American woodcock was used as a surrogate for the American robin, and the percentage of soil in the diet of the opossum was used as a surrogate for the short-tailed shrew. Beyer et al. (1994) did not publish percentages of soil/sediment in diets of piscivorous species such as the belted kingfisher. However, the belted kingfisher would likely have a lower percentage of soil/sediment in the diet than the omnivorous water fowl such as blue-winged teal and ring-necked duck, which both have 2% soil in diet (Beyer et al. 1994). Therefore, the percentage of soil/sediment in the diet of the belted kingfisher was assumed to be 1%. The sediment ingestion rate of the mallard, which dabbles in submerged aquatic vegetation, was reported as 3.3% in Beyer and Fries (2003). Tree swallows were assumed to not come into contact with sediment or soil, because they forage aerially. For all other receptors, the body-weight-normalized soil/sediment ingestion rate was calculated from the dry-weight-normalized food ingestion rate ($NFIR_{dry}$) and percentage of sediment/soil in diet.

The water ingestion rates for the wildlife receptors (Table 15), except for the short-tailed shrew, were estimated using the body-weight-normalized water ingestion rate equations published by

Calder and Braun (1983). The water ingestion rate for the short-tailed shrew was taken from Chew (1951, as cited in U.S. EPA 1993).

Body weights for the chosen receptors were based on information included in the *Wildlife Exposure Factor Handbook* (U.S. EPA 1993). However, there was no body-weight information specific to Montana or nearby regions. For example, the body weights for American robin and tree swallow included in Table 15 were averages reported from New York State studies. The body weights of the belted kingfisher and short-tailed shrew were from Ohio and northern Pennsylvania, respectively. The mink and mallard body weights were averages from throughout North America. In an effort to make the BERA specific to the project site, a literature search for body weights specific to the Montana region, or nearby, will be conducted, and the results will be provided in a separate technical memorandum as an interim deliverable to the draft BERA. Foraging-area sizes and the dietary fractions for each type of prey item will also be reviewed and selected based on Montana-specific, or regionally representative, studies. The selected foraging ranges and dietary fractions for each receptor will also be described in the technical memorandum.

6.4 Characterization of Ecological Effects

This section presents the approach for the second part of the analysis phase of the BERA, the characterization of ecological effects. The effects assessment summarizes and weighs available lines of evidence, or measures of effect (Section 4.6), regarding the potential for contaminants to cause adverse effects in exposed individuals. These adverse effects may include impacts on growth, reproduction, and survival. Various approaches will be used to characterize the potential for effects on ecological receptors:

- For wildlife (birds and mammals), the approach will be to:
  - Compare concentrations of metals in composite soil and sediment samples to background levels and risk-based screening benchmarks (for soil) such as U.S. EPA's EcoSSLs.

- Compare estimated dietary doses (using measured concentrations of metals in plants, prey, soil, sediment, and surface water) to toxicity reference values (TRVs) derived from the scientific literature.

- Make qualitative observations regarding habitat quality and ecosystem health.

- For benthic invertebrates, the approach will be to:

  - Compare CoPC concentrations in sediment to background concentrations and established benchmarks or SQGs that are predictive of adverse effects.

  - Evaluate sediment toxicity test results for Prickly Pear Creek adjacent to and downstream of the site, and compare to results from upstream reference locations.

  - Assess metals bioavailability in sediments using AVS/SEM, grain size, TOC, and pH data.

- For fish, the approach will be to:

  - Compare concentrations of metals in surface water (and hyporheic water for the groundwater-surface water interface) to Montana Numeric Water Quality Standards for Aquatic Life, or other screening benchmarks.

  - Compare concentrations of metals in prey fish, benthic invertebrates, and larger predatory fish to dietary effects levels and tissue-based benchmark values (where available) to evaluate the potential for adverse effects on the survival and reproduction of higher-trophic-level fish.

- For upland and wetland plants, the approach will be to:
  - Compare concentrations of metals in composite soil (for upland plants) and sediment/surface water (for aquatic plants) to background levels and risk-based screening benchmarks such as EPA's EcoSSLs for plants, and ORNL toxicological benchmarks for plants (Efroymson et al. 1997b).
  - Make qualitative observations regarding plant community health.
- For soil invertebrates, the approach will be to:
  - Compare concentrations of metals in composite soil to background levels and risk-based screening benchmarks such as EPA's EcoSSLs for invertebrates, and ORNL toxicological benchmarks for soil invertebrates (Efroymson et al. 1997a).
  - Assess metals bioavailability in soil using grain size, TOC, and pH data.

6.4.1 Adverse Effects of Metals

Organisms have evolved homeostatic mechanisms that regulate the uptake and excretion of metals to maintain tissue concentrations within desirable ranges, as well as to prevent toxicity (Kapustka et al. 2004). For certain elements and organisms, bioaccumulation is required to maintain the organism's health and normal function; this is the case for essential trace elements such as copper and zinc. In other situations, bioaccumulation of metals produces residues in plants and animals that cause direct toxicity (e.g., copper toxicity to aquatic organisms) or indirect toxicity to consumers (as in selenium accumulation by plants). To further complicate understanding the bioaccumulation and metabolism of metals, the metabolism of an essential element can affect the metabolism of a non-essential toxic metal, as in the case of calcium and lead in the central nervous system (Kern et al. 2000). Nonessential metals, such as arsenic and lead, are not required for biological processes and are therefore not naturally regulated by the body. These metals may cause toxicity at various exposure levels.

Chronic dietary exposure to toxic levels of metals may cause a variety of effects in mammals and birds, including weakness, paralysis, conjunctivitis, dermatitis, decreased growth, liver and kidney damage, neurological damage, reproductive failure, and developmental effects in offspring, depending on the metal of concern (Eisler 1988). The degree of toxicity and the rate of uptake of metals are dependent on the chemical form and the geochemical properties of the medium where it is found. For example, the methylated form of mercury is more toxic to wildlife and more bioaccumulative than the ionic form. Water hardness also affects the degree of toxicity of cadmium, chromium, copper, lead, nickel, silver, and zinc—toxicity decreases with increasing hardness. In aquatic systems, the toxic effects of metals can range from reductions in growth to mortality. The most sensitive organisms are generally early life stages of benthic organisms and fish.

6.4.2 Toxicity Reference Values

For all representative receptors, exposure estimates will be compared to TRVs to calculate hazard quotients (HQs). TRVs are expressed as a daily dietary dose, and will be calculated from dietary exposure endpoints according to the following general formula:

$$TRV = ([diet] \times IR)/BW$$

where:

TRV	=	toxicity reference value (mg/kg body weight per day)
[diet]	=	dietary concentration (mg/kg food or mg/L drinking water) associated with a given endpoint
IR	=	daily ingestion rate (kg food/day or L drinking water/day)
BW	=	body weight (kg).

The no-observed-adverse-effect level (NOAEL) and lowest-observed-adverse-effect level (LOAEL)-based TRVs that will be used for the BERA are listed in Table 16. The NOAEL is the highest concentration of a chemical at which no adverse effects are observed in the test species. Because the NOAEL represents a body-weight-normalized daily intake rate of a chemical that did not elicit any adverse responses in the test organism, exceedance of this value does not necessarily imply that adverse effects would occur for ecological receptors. The LOAEL is the lowest concentration of a particular chemical at which adverse effects are observed in the test species. Thus, an exposure rate in excess of the LOAEL-based TRV indicates a greater potential for adverse effects.

Oral TRVs for fish are available for arsenic, cadmium, copper, lead, and zinc from the supplemental ERA (U.S. EPA 2005b) from the Clark Fork River, Montana, ecological risk assessment (refer to Table 5-7 from the Supplemental ERA). These values are based on NOAELs and LOAELs and will be compared to the estimated metals concentrations in the diet of predatory fish to develop risk estimates for fish. The fish oral TRVs are presented in Table 17.

Sources of the TRVs for avian and mammalian species include the EPA's EcoSSLs,[13] Sample et al. (1996), and the scientific literature. EPA recently developed EcoSSLs for a number of metals (antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, nickel, selenium, silver, vanadium, and zinc), as well as other chemicals. In developing the EcoSSLs, EPA extensively reviewed the toxicological literature and selected studies to form the basis for wildlife TRVs. The key studies that form the basis of the EcoSSLs were reviewed for possible use in developing the wildlife TRVs for the BERA.

The selection of TRVs requires the use of professional judgment. Because the intent of the BERA is to assess risk to populations (U.S. EPA 1997), laboratory studies reviewed for TRV derivation were evaluated for the measurement endpoints that are relevant for receptors on a population level: development, reproduction, and survival. Chronic dietary exposure studies were preferred, because they best represent wildlife exposure conditions. For some chemicals with little or no published toxicological information, studies measuring alternative endpoints or with shorter exposure durations had to be used for TRV derivation, as discussed below.

[13] Online at http://www.epa.gov/ecotox/ecossl/.

A number of considerations were used when selecting a study for TRV derivation, including:

- Test species relevance to receptor species — Ideally, studies on wildlife species are preferred for TRV development; however, very few toxicological studies on wildlife species have been conducted. Therefore, studies on laboratory rodents (e.g., rats and mice) and common avian test species (e.g., Japanese quail) were reviewed and considered for TRV development. Studies with domesticated species, such as chickens, cattle, pigs, and dogs, were also considered for TRV development, when studies for wildlife species or common laboratory test species were not available.

- Relevant exposure route — The preferred route of exposure for TRV derivation is via food. Exposure in food provides a better estimate of wildlife exposure to chemicals in the environment than exposure by gavage, oral capsule, or in drinking water. Inorganic and organic chemicals dissolved in drinking water or a capsule are typically in forms (e.g., inorganic salts) that are much more bioavailable than the forms in which a chemical would be found in the environment, and thus would not produce realistic assessments of potential environmental toxicity. Given that metals and organic chemicals partition from water to food, soil, or sediment in the environment, these exposure routes are not as relevant as in food. Other exposure routes such as gavage or drinking water were considered for TRV derivation only in cases where no appropriate feeding studies were available.

- Study of chronic duration — Studies of chronic duration are preferred over short-term or acute studies for TRV derivation. For mammals, a study is considered chronic if the exposure was at least one-half of the test animal's lifespan or occurred during a critical life stage, such as reproduction and development. For birds, a study was considered chronic if the exposure was at least 10 weeks or occurred during reproduction or development.

- Provide adequate controls — Laboratory studies without adequate controls were not considered for TRV development. Laboratory studies with a control group exposed to an exposure medium without chemicals added were preferred over field studies where such controls do not exist.

- Adequate statistical methods — Studies that conducted appropriate statistical analyses to determine the significant differences between the control and treatment groups were preferred.

- Adequate sample size — A sample size of three is required for consideration in the TRV development. Studies with larger sample sizes are preferred.

- Daily dose or adequate dosing information — Studies that report the effect concentrations as daily doses (e.g., milligrams chemical per kilogram body weight per day, mg/kg-d) or information necessary to calculate the daily dose (e.g., test-animal ingestion rate or body weight and food consumed) were preferred over studies lacking this information.

- Reproductive, growth, or survival endpoints — Studies that report effects on ecologically relevant endpoints, including reproduction, growth, and survival, were considered for TRV development. Behavioral, pathological, biochemical, or physiological endpoints were not considered for TRV development unless they were linked to the ecologically relevant endpoints. Reproductive endpoints were preferred to growth and survival.

- Absence of confounding factors — Studies that controlled for confounding factors are preferred. For example, studies that exposed test organisms to multiple chemicals were not used for TRV development.

- Provides a dose-response — Studies that demonstrate increasing chemical levels related to increasing severity of effect are preferred, because they provide evidence that the treatment is the cause of the observed effect.

- Report both a NOAEL and a LOAEL — Studies that report both a NOAEL and LOAEL are preferred, because these studies (1) report the statistically-significant-effect level and (2) bound the adverse-effect level, thus reducing uncertainty in the use of the study to develop TRVs.

- If IR and BW were not provided in the source study, they were estimated from data in other published sources. Ingestion rates can be calculated using appropriate allometric equations such as from Calder and Braun (1983), Nagy (1987), or U.S. EPA (1993).

- [diet] and IR must be expressed on the same mass basis (e.g., either wet weight [ww] or dry weight [dw]).

- If only subchronic studies were available for selecting chronic TRVs, an acute-to-chronic ratio of 10 (Sample et al. 1996) was applied. If only a LOAEL was provided by the authors of the selected study, then the LOAEL was divided by a factor of 10 to derive the NOAEL benchmark.

- Doses of metal salts of less than 100% purity were adjusted by multiplying the dose by the percent molecular weight. This is consistent with the EPA EcoSSL TRV development methodology.

Below are descriptions of the studies used to develop the wildlife TRVs, including discussions regarding the EPA EcoSSLs for each metal.

6.4.2.1 Aluminum

Birds: Very few studies on the ecologically relevant effects of aluminum in birds have been published, and EPA does not provide an EcoSSL for aluminum for birds. The TRV for the BERA was derived from a study by Carriere et al. (1986), where ringed doves were dosed with aluminum sulfate in food for 4 months. Because there were no significant reproduction differences observed at a dose of 1,000 ppm over the critical life stage (reproduction), this dose was considered to be an avian no-effect dose. The 1,000-ppm dose was based on wet weight in food and equates to 1,111 ppm dry weight, assuming a 10% moisture content for prepared laboratory food. Based on a ringed dove food ingestion rate of 0.0173 kg/d (calculated with an allometric equation from Nagy 1987) and a body weight of 0.155 kg (Terres 1980), a NOAEL TRV was calculated to be 124 mg/kg-day. No appropriate study could be found to identify an avian LOAEL TRV.

Mammals: No studies on aluminum toxicity in mammalian wildlife were found, and EPA does not provide an EcoSSL for aluminum for mammals. The mammalian TRV for aluminum the BERA is based on a study by Ondreicka et al. (1966) in which mice were exposed to aluminum chloride (a soluble salt) in drinking water at 19.3 mg/kg-day for 390 days (three generations). No significant effect was noted with regard to number of litters or number of offspring. However, the treatment group did manifest reductions in weight gain in the second and third litters of the second generation and the first and second litters of the third generation. This significant reduction in pup growth was considered the LOAEL. Because no lower dose level was tested, a 0.1 level of uncertainty was applied to estimate the no-effects TRV at 1.93 mg/kg-day.

6.4.2.2 Antimony

Birds: No avian studies suitable for antimony TRV derivation were located in the literature. EPA does not provide an EcoSSL for antimony for birds, because all of the studies they reviewed were rejected as inappropriate for TRV derivation. Therefore, no avian TRVs could be developed for antimony.

Mammals: The EPA EcoSSL for antimony was derived from a reproductive study on rats by Rossi et al. (1987), which was also selected to derive the mammalian TRVs for the BERA. In this study, Rossi et al. (1987) exposed pregnant rats to 1 and 10 mg/L antimony trichloride (53.38% antimony by molecular weight) in drinking water for 31 days. Pups were also exposed postnatally via nursing. A significant decrease in pup body weight was observed at 10 mg/L in drinking water (LOAEL). This study was considered appropriate, because animals were exposed during critical life stages (gestational females and nursing pups). Although this study did not provide the daily dose or the water ingestion rate, maternal body-weight data were provided so that the daily dose could be estimated. Using a rat body weight of 0.33 kg and intake rate of 0.13 L/kg-day, and adjusting for 53.83% antimony by molecular weight, the resulting NOAEL is 0.07 mg/kg-d, and the LOAEL is 0.72 mg/kg-d for mammals.

6.4.2.3 Arsenic

Birds: The selected avian TRVs for arsenic are 16 mg/kg-d (NOAEL), and 40 mg/kg-d (LOAEL), based on mallard reproductive effects from exposure to sodium arsenate (As^{5+}), derived from the study by Stanley et al. (1994). The EPA EcoSSL TRV for arsenic for birds is from a study on chickens by Holcman and Stibilj (1997). This study was not considered in the TRV derivation process for this BERA, because chickens are not the most appropriate surrogate species for wildlife receptors, and other studies on more suitable species are available, including that by Stanley et al. (1994) described here. In this study, mallards were fed feed mixed with sodium arsenate for 115–128 days during reproduction at arsenic concentrations in feed of 0, 25, 100, or 400 mg/kg. Arsenic did not affect hatching success or embryo deformity rates at any dose level; however, the highest dose resulted in an increase in the number of days between pairing and laying of the first egg, and a decrease in whole-egg weight and shell thickness. Duckling production and growth decreased when diets were supplemented with 400 mg/kg arsenic (LOAEL). At 100 ppm in the feed, there was no effect on duckling production (NOAEL). Assuming a mallard body weight of 1.0 kg and an ingestion rate of 0.100 kg/day (Heinz et al. 1989), the arsenic NOAEL TRV was calculated to be 10 mg/kg-day, and the LOAEL to be 40 mg/kg-day.

Mammals: Nemec et al. (1998) evaluated the developmental toxicity of arsenic to rabbits (New Zealand white strain). This study was considered more appropriate for TRV derivation for the BERA than the study used by EPA for the EcoSSL, because it was conducted during a critical life stage and assessed both reproductive and survival endpoints. The EPA EcoSSL mammalian TRVs for arsenic are from a study by Neiger and Osweiler (1989) conducted on beagle dogs based on the growth endpoint, fraction of initial body weight. In this study, inorganic arsenic (sodium arsenite; As^{3+}) in feed resulted in feed rejection, which resulted in reduced body weight. In the study used for TRV derivation for this ERA, Nemec et al. (1998) provided rabbits with arsenic acid (As^{5+}) by oral gavage on gestation days 6 through 18 at 0, 0.19, 0.75, or 3.0 mg/kg-day. The rabbits were sacrificed on gestation day 29. Maternal effects, including mortality, slight decreases in body weight, and clinical signs of toxicity, occurred only at the highest dose level. There were no statistically significant effects on embryos or fetuses at this dose, although there was a slight decrease in the number of viable fetuses per litter. No maternal or offspring effects were seen at 0.75 mg/kg-day (NOAEL). The 3.0 mg/kg-day dose represents a chronic LOAEL. Although this study was of subchronic duration, no uncertainty factor was applied, because the exposure was to fetuses during gestation, which is a sensitive life stage (Sample et al. 1996).

6.4.2.4 Barium

Birds: EPA does not provide EcoSSL TRVs for birds, and all of the studies except one (Johnson et al. 1960) were rejected for use in deriving an avian TRV. This study was used to develop the barium TRVs for birds in this evaluation. Johnson et al. (1960) fed 1-day-old chicks 0, 250, 500, 1000, 2000, 4000, 8000, 16000, or 32000 ppm Ba as barium hydroxide in feed to groups of twenty female chicks for four weeks. The 2000-ppm Ba diet had no effect on mortality. There was a slight depression in growth of chicks that ate the 2000-ppm Ba diet, but this was not significant. The 4000- to 32000-ppm diets resulted in 5% to 100% mortality. This study did not provide information needed to develop a daily dose, and body weight and ingestion rate were assumed. This study was four weeks long and considered to be a subchronic exposure, and a subchronic-to-chronic uncertainty factor of 0.1 was applied to the NOAEL and LOAEL. The resulting NOAEL TRV is 21 mg/kg/d, and the LOAEL TRV is 42 mg/kg/d.

Mammals: The EPA EcoSSL TRV for Ba for mammals is a NOAEL of 51.8 mg/kg/d. EPA states that the NOAEL is based on the geometric mean of NOAELs for reproduction and growth, and is lower than the lowest bounded NOAEL for reproduction, growth, and survival. The EPA EcoSSL is based on two studies: Borzelleca et al. (1988) and Dietz et al. (1992). Borzelleca et al. (1988) administered barium chloride to juvenile rats for 10 days and observed reduced survival at 209 mg/kg/d. Dietz et al. (1992) exposed juvenile rats to barium chloride by gavage for 92 days and observed reduced growth in developing male rats at 121 mg/kg/d. The study by Dietz et al. (1992) was selected to develop the TRVs, because it was a longer study and reported effects on a more sensitive endpoint than the study by Borzelleca et al. (1988). The study by Dietz et al. (1992) is considered subchronic, and an uncertainty factor of 0.1 is applied to the NOAEL and LOAEL. The resulting NOAEL is 6.1 mg/kg/d and the LOAEL is 12 mg/kg/d.

6.4.2.5 Beryllium

Birds: No studies were located on ecologically relevant effects of beryllium in birds, and EPA does not provide an EcoSSL for birds. Therefore, no avian TRVs could be developed for birds.

Mammals: The EPA EcoSSL TRV for beryllium is based on a life-term study conducted on rats by Schroeder and Mitchener (1975), which was also selected for TRV derivation for the BERA. In this study, a slight depression on growth was observed in rats given drinking water with 5 mg/L beryllium from 2 to 6 months of age, but this was not a lasting effect even though exposure continued up to 6 months. At the next time periods tested (12 and 18 months of age), there was no depression in growth in beryllium-treated rats. Therefore, this can be considered a chronic no-effect concentration. No other effects on rats from barium exposure were observed. There is low confidence in this TRV, because a LOAEL was not determined, only one control and one treatment group were used, and daily dose information was not provided. However, the endpoint was ecologically relevant and the exposure duration was chronic. The resulting NOAEL TRV for this BERA is 0.66 mg/kg-d.

6.4.2.6 Cadmium

Birds: The selected avian TRVs for cadmium for this ERA are based on mallard reproductive effects (egg production) observed by White and Finley (1978). In this study, adult mallards were fed breeder mash with cadmium chloride for 90 days. Egg production was significantly suppressed in the mallards fed 210 ppm cadmium (LOAEL), whereas mallards fed 1.6 to 15.2 ppm cadmium were not affected (NOAEL). The test species had a body weight of 1.153 kg and a food consumption rate of 0.110 kg/d. Therefore, 15.2 ppm cadmium (1.45 mg/kg-day) was considered the chronic NOAEL TRV, and 210 ppm cadmium (20 mg/kg-day) was considered the LOAEL TRV for birds. The EPA EcoSSL avian TRV for Cd for birds is 1.47 mg/kg-d, a NOAEL based on the geometric mean of NOAELs for reproduction and growth, and most of these are studies on chickens. Chickens are generally not good surrogate species for mallard or other wildlife species. In fact, in some cases such as for PCBs, chickens have been shown to be among the most sensitive of bird species. Therefore, when data for a more relevant avian species were available, as in the case of cadmium, chicken studies were eliminated from consideration in the TRV derivation process for the BERA.

Mammals: The mammalian TRVs for cadmium were developed from a study by Sutou et al. (1980) on rats. Sutou et al. (1980) exposed rats to cadmium, as cadmium chloride, at four dose levels (0, 0.1, 1.0, and 10 mg/kg-day) by oral gavage through the mating and gestation period (6-week exposure period). Adverse reproductive effects (i.e., reduced fetal implantations, reduced fetal survivorship, and increased fetal resorption) were observed in the rats exposed to 10 mg/kg-day. Therefore, the 1.0-mg/kg-day dose was considered to be the chronic NOAEL TRV, and a dose of 10 mg/kg-day was considered the LOAEL TRV for the evaluation of risk to mammals. This Sutou et al. (1980) feeding study with reproductive endpoints was determined to be more appropriate for TRV derivation than the study used as the basis of the EPA EcoSSL, because the EcoSSL TRV is from a study by Yuhas et al. (1979) in which rats were dosed via drinking water and the endpoint was growth.

6.4.2.7 Chromium

Birds: The avian TRV for chromium was based on the study by Haseltine et al. (1985) in which black ducks were exposed to chromium (Cr^{3+}, as $CrK(SO_4)_2$) at two dose levels—10 and 50 ppm in food for 10 months through reproduction. No effects on reproduction were observed at the lower dose of 10 ppm chromium (11 ppm dry weight). The assumptions used in the TRV calculations included a body weight of 1.25 kg (Dunning 1993) and a food consumption rate of 0.0785 kg/kg-day for the test species (based on a reasonable maximum energy [RME] requirement of 200 kcal/kg-day derived from Nagy [1987], an assimilation efficiency of 80%, and an energy content of 3,190 kcal/kg dry weight). Therefore, the NOAEL TRV was determined to be 0.86 mg/kg-day. The LOAEL was determined to be 4.32 mg/kg-day based on the 50-ppm treatment. The Haseltine et al. (1985) study on black ducks was considered more relevant for TRV derivation than the EPA EcoSSL TRV, 2.66 mg/kg-d (NOAEL), based on the geometric mean of NOAELs for reproduction and growth. The collection of studies consists mostly of chicken and turkey studies, many of which present NOAELs but not LOAELs. Chickens and turkeys as receptors are not as ecologically relevant as black ducks.

Mammals: A study by Zahid et al. (1990) was the source of the lowest LOAEL used by EPA in developing the EcoSSL TRV for chromium (Cr^{3+}). In this study, mice were fed 100, 200, or 400 mg/kg chromium sulfate (38.02% chromium by molecular weight) for 35 days. Dietary chromium sulfate decreased sperm count at all doses tested. This study provided information needed to calculate the daily dose, and the resulting LOAEL for chromium is 5.96 mg/kg-d. To estimate a NOAEL, the LOAEL was divided by 10, resulting in a NOAEL of 0.596 mg/kg-d.

6.4.2.8 Cobalt

Birds: The EPA EcoSSL TRV for Co for birds is a NOAEL of 7.61 mg/kg/d. EPA states that the NOAEL is based on the geometric mean of NOAELs for growth (there were no studies on reproduction), which are mostly based on studies with chickens. Chickens are not always good surrogate species for mallard or other wildlife species, as discussed above. Therefore, chicken studies were eliminated from consideration in this TRV derivation process when data for a more relevant species were available. The only other study from the EPA EcoSSL list that was relevant was a study by Paulov (1971), which reported both a NOAEL and LOAEL for the effects of Co on the growth of mallards. In this study, juvenile (2-day-old) mallards were fed commercial diet with $CoCl_2$ for 8 days. Growth was significantly lower in the mallards fed 2,000 ppm Co (LOAEL), whereas mallards fed 200 ppm Co were not affected (NOAEL). The resulting NOAEL and LOAEL for Co based on this study are 4.1 mg/kg/d and 41 mg/kg/d, respectively.

Mammals: The EPA EcoSSL TRV for Co for mammals is a NOAEL of 7.33 mg/kg/d. EPA states that the NOAEL is based on the geometric mean of NOAELs for reproduction and growth. A key study used to develop the EcoSSL TRV for Co is a study by Nation et al. (1983). This study was the source of the lowest NOAEL and LOAEL used by EPA in the development of the EcoSSL TRV for Co. Other studies listed by EPA used non-preferred routes of exposure, were of shorter duration than Nation et al. (1983), or did not report both NOAELs and LOAELs. In the Nation et al. (1983) study, mature rats received 0, 5, or 20 mg Co/kg/d in food for 69 days. While rats in the 20-mg/kg/d group exhibited testicular atrophy, rats in the 5-mg/kg/d group did not. Because the exposure duration was less than one-half of the lifespan of the rat, a subchronic-to-chronic uncertainty factor of 0.1 was applied to the daily doses. Therefore, the Co NOAEL is 0.5 mg/kg/d, and the LOAEL is 2.0 mg/kg/d.

6.4.2.9 Copper

Birds: The EPA EcoSSL TRV for Cu for birds is a NOAEL of 4.05 mg/kg/d. EPA states that the NOAEL is the highest bounded NOAEL below the lowest bounded LOAEL for reproduction, growth, and mortality. The EPA NOAEL is based on a chicken study (Ankari et al. 1998). Chickens are not good surrogate species for mallard or other wildlife species (in some cases, chickens have been shown to be among the most sensitive of bird species). Therefore, chicken studies were eliminated from consideration in this TRV derivation process when data for a more relevant species were available. The only other study from the EPA EcoSSL list that was relevant (i.e., for a relevant species, reported a NOAEL and LOAEL, and for a relevant endpoint) was Foster (1999). In this study, juvenile ducks were fed 0, 218.5, 420, or 1024 ppm Cu in food for 34 days, and reduced growth was observed in the 420-ppm group, but growth was not affected in the 218.5-ppm group. This study reported information needed to calculate daily doses, and the resulting NOAEL is 56.8 mg/kg/d and LOAEL is 109 mg/kg/d. Because the exposure duration of this study was only 35 days, a subchronic-to-chronic uncertainty factor of 0.1 was applied. The final Cu NOAEL for birds is 5.68 mg/kg/d, and Cu LOAEL for birds is 10.9 mg/kg/d.

Mammals: The EPA EcoSSL TRV for Cu for mammals is a NOAEL of 5.06 mg/kg/d. EPA states that the NOAEL is the highest bounded NOAEL below the lowest bounded LOAEL for reproduction, growth, and mortality. The EPA NOAEL is based on a mink study (Aulerich et al. 1982). Other available Cu mammalian studies that reported both NOAELs and LOAELs for relevant endpoints were not considered in this TRV selection process, because the study durations were shorter than the study by Aulerich et al. (1982). Aulerich et al. (1982) fed juvenile mink a diet with added amounts of copper (0, 25, 50, 100, or 200 ppm) in food for 357 days. The feed without addition of Cu contained 60.5 ppm; this base level of Cu should be added to the Cu doses. Kit mortality was observed in the 50-ppm group, but not the 25-ppm group. This study did not provide necessary information to estimate the daily doses, and body weight and ingestion rate values were assumed. The NOAEL is 11.7 mg/kg/d (25 mg/kg diet + 60.5 mg/kg in food * 0.137 kg food/kg body weight/d), and the LOAEL is 15.1 mg/kg/d (50 mg/kg diet + 60.5 mg/kg in food * 0.137 kg food/kg body weight/d).

6.4.2.10 Lead

Birds: The lead NOAEL-based TRV for birds was developed from the study by Pattee (1984), in which American kestrels were fed lead in food for seven months. Pattee (1984) dosed American kestrels with metallic lead in the diet (0, 10, or 50 ppm) for 5−7 months prior to and during clutch completion. Key results of this study included no effects on body weight, food consumption, clutch initiation, interval between eggs, clutch size, fertility, or eggshell thickness at any dose level. Results indicated that the highest tested dose (50 ppm) represented a no-effect level. Because the dosing lasted 7 months and included a critical lifestage (reproduction), the study can be considered a chronic exposure. Using the body weight reported in the study and a food ingestion rate of 10 g/day (Sample et al. 1996), the resulting lead NOAEL TRV for birds is 3.85 mg/kg-d. The EPA avian EcoSSL TRV for lead is based on a study by Edens and Garlich (1983) using chickens. Chickens are not a good surrogate species for mallard or other wildlife species. Therefore, when data for a more relevant species such as kestrel were available, chicken studies were eliminated from consideration in the TRV derivation process for the BERA.

The LOAEL-based avian TRV for lead was developed from a study by Edens et al. (1976). In this study, Japanese quail received dietary exposure to lead (0, 1, 10, 100, or 1,000 ppm as lead acetate) from hatching to 12 weeks of age, through reproduction. The key result of this study was the observation of a significant decrease in percent hatch of settable eggs at 100 ppm and higher (59.1 percent for this dose group, versus 81.6 percent for control group and 82.4 percent for the 10-ppm group). Therefore, 100 ppm lead was considered to be a chronic LOAEL dose. Assuming a body weight of 0.15 kg from Vos et al. (1971) and a food consumption rate of 0.0169 kg/day (based on allometric equation from Nagy 1987), a LOAEL TRV of 11 mg/kg-day was derived.

Mammals: The mammalian TRVs for lead were developed from a study by Azar et al. (1973) that examined effects on reproductive performance in rats over three generations. Various dose levels were tested (5, 18, 62, 141, 1,130, and 2,102 ppm lead as lead acetate measured in food). None of the lead dose levels affected the number of pregnancies, number of live births, or other reproductive indices. The two highest doses reduced offspring weights and produced kidney damage in young. Therefore, 1,130 mg/kg concentration in food, or 90 mg/kg-day (based on a body weight of 0.35 kg and an ingestion rate of 0.028 kg/day from U.S. EPA 1988), was considered the LOAEL TRV. The no-effects dose was 141 mg/kg in food, which corresponds to a TRV of 11 mg/kg-day. The EPA EcoSSL TRV for lead in mammals is based on a study that dosed rats with lead in drinking water, which is not the preferred exposure route. Therefore, the study by Azar et al. (1973) was the preferred study for TRV development.

6.4.2.11 Manganese

Birds: A study by Vohra and Kratzer (1968) was the source of the avian TRVs for manganese. In this study, turkey poults were fed 0, 510, 1020, 2040, 3000, 3060, 3620, 4080, or 4800 ppm manganese in food for 21 days. Growth was significantly lower in the turkeys fed 4800 ppm manganese (LOAEL), whereas turkeys fed 4080 ppm were not affected (NOAEL). This study provided body weight and an ingestion rate to calculate the daily doses. Because the exposure duration was 3 weeks, a subchronic-to-chronic uncertainty factor of 0.1 was applied to the TRVs. The resulting NOAEL and LOAEL for manganese are 26 mg/kg-d and 30 mg/kg-d, respectively. The EPA EcoSSL avian TRV for manganese is 179 mg/kg-d (NOAEL). EPA states that this value is based on the geometric mean of NOAELs for reproduction and growth, which are mostly based on studies with chickens. EPA lists only one study, the one by Vohra and Kratzer (1968), that is the basis for the BERA TRVs. This study used a more appropriate test species, the preferred route of exposure (oral in food), and both a NOAEL and LOAEL for an ecologically relevant endpoint.

Mammals: The mammalian TRVs for manganese were derived from the study by Laskey et al. (1982), in which rats were fed 0, 250, 1050, or 3500 ppm manganese in food for 224 days. This study is appropriate for development of TRVs, because the researchers used the preferred exposure route (oral in food), an appropriate test organism (the rat), ecologically relevant endpoints (reproduction) and a sufficient exposure duration. The percentage of pregnant rats was significantly lower in the 3500-ppm (LOAEL) group than in the control group, whereas the percentage of pregnant rats was not significantly different in the 1050-ppm (NOAEL) group from the control group. This study did not provide daily doses, or body weight and ingestion rate to calculate the daily doses, and therefore, these values were assumed. Using a body weight of 0.35 kg (U.S. EPA 1995) and ingestion rate of 0.028 kg/d (calculated using an allometric equation from U.S. EPA 1988) for the rat, the resulting NOAEL and LOAEL TRVs for manganese are 88 mg/kg/d and 280 mg/kg/d, respectively. The EPA EcoSSL TRV for manganese is based on the geometric mean of NOAELs for reproduction and growth. Of the studies that EPA lists, many of them use inappropriate test species, do not use the preferred route of exposure (oral in food), or do not provide both a NOAEL and LOAEL for an ecologically relevant endpoint.

6.4.2.12 Total Mercury

Birds: EPA does not provide a mercury EcoSSL for birds. However, there are sufficient studies on avian species to derive mercury TRVs. A study on Japanese quail by Hill and Schaffner (1976) was selected for the avian TRV derivation process, because this study used the preferred route of exposure, was of adequate duration, and measured appropriate toxicological endpoints. In this study, groups of Japanese quail were fed mercuric chloride in food at 0, 2, 4, 8, 16, or 32 mg/kg for one year during reproduction. Fertility and hatching success decreased at 8 mg/kg and higher dose levels. The NOAEL was considered to be 4 mg/kg in diet, and the LOAEL was considered to be 8 mg/kg in diet. Using a 0.15-kg body weight for quail (Vos et al. 1971), and an ingestion rate determined by allometric equation (Nagy 1987), the resulting NOAEL and LOAEL TRVs for total mercury are 0.74 and 1.5 mg/kg-d, respectively.

Mammals: EPA does not provide a mercury EcoSSL for mammals. However, there are sufficient studies on mammalian species to derive mercury TRVs. Studies on mink by Aulerich et al. (1974), and mouse by Dieter et al. (1983), were selected for the mammalian TRV derivation process, because these studies used the preferred route of exposure, duration, and toxicological endpoints. In the study by Aulerich et al. (1974), groups of mink were fed mercuric chloride in food at 0 or 7.39 ppm for 6 months during reproduction and fertility, offspring survival and weight were not significantly reduced (NOAEL). In the study by Dieter et al. (1983), mice exposed to mercury in water at 75 ppm for 7 weeks exhibited significantly lower body mass (LOAEL). Using the body weights and ingestion rates for mink and mouse in Table 15, the resulting NOAEL and LOAEL TRVs for total mercury based on these studies are 1.0 and 18.8 mg/kg-d, respectively.

6.4.2.13 Methyl Mercury

Methylmercury TRVs were included as effects measures for mercury in addition to total mercury, because this CoPC typically occurs in a methylated form in biological tissues (food items), which tend to contribute more mercury to the total exposure than drinking water or incidental ingestion of soil or sediment.

Birds: The TRV used to evaluate the effects of methylmercury in birds was based on a three-generation study by Heinz (1974, 1976a,b, 1979) in mallards. Mallard ducks were exposed to dietary concentrations of methylmercury dicyandiamide ranging from 0.5 to 3.0 mg/kg dry weight for two generations, with the third generation exposed to 0.5 mg/kg-day. The initial test birds (P1) showed no behavioral or reproductive effects at the lowest methylmercury concentration. However, the second-generation ducklings (F2), demonstrated a 29% reduction in 1-week survival rates at 0.5 mg/kg methylmercury (Heinz 1976a). Neither the first generation (F1) nor the third generation (F3) showed decreased survival at this dose level. The impact over the three generations was reported to be an 18% reduction in productivity overall. Based on a food intake rate of 128 g/kg body weight (as reported by Heinz 1979), and a body weight of 1.0 kg for the treated F1 and F2 females, this represents a LOAEL of 0.064 mg/kg body weight-day. No long-term studies were identified as suitable for the derivation of a no-effects level for methylmercury exposure to birds. Therefore, an uncertainty factor of 0.5 was applied to estimate a NOAEL TRV of 0.032 mg/kg-day from the LOAEL, as recommended by U.S. EPA (1995).

Mammals: The TRV for methylmercury for mammals was based on a study by Verschuuren et al. (1976). Rats were dosed with three dose levels of 0.1, 0.5, and 2.5 ppm of methylmercury chloride in food. The study took place over three generations, and reproduction was used as the toxicity endpoint. Adverse effects were not observed at the two lower doses, although exposure to 2.5 ppm reduced pup viability. The 0.5-ppm dose was considered the no-effect dose, and with a body weight of 0.35 kg (U.S. EPA 1988) and a food consumption rate of 0.028 kg/day (U.S. EPA 1988), the NOAEL was calculated to be 0.032 mg/kg-day. The lowest-effect dose was considered to be 2.5 ppm, and the LOAEL was calculated to be 0.16 mg/kg-day.

6.4.2.14 Nickel

Birds: A study by Cain and Paddford (1981) on mallards was used to develop the avian TRVs for nickel. In this study, Cain and Paddford (1981) fed juvenile mallards 0, 200, 800, or 1200 ppm nickel (as nickel sulfate) in food for 90 days. Growth and survival were significantly lower in the 800-ppm (774 ppm nickel) group, but were unaffected in the 200-ppm (176 ppm nickel) group. The body weight and ingestion rate were provided in this study, and daily doses for the 200-ppm (NOAEL) and 800-ppm (LOAEL) groups were calculated. The resulting NOAEL is 31 mg/kg-d, and the LOAEL is 135 mg/kg-d. The EPA EcoSSL TRV is based on the geometric mean of NOAELs for reproduction and growth, which are mostly based on studies with chickens. Therefore, the study by Cain and Paddford (1981), which provides both a NOAEL and LOAEL for mallards, was selected as the preferred study for TRV derivation.

Mammals: A study by Ambrose et al. (1976), in which rats were fed nickel in food (0, 250, 500, or 1000 ppm) for three generations, was selected for the mammalian TRV development. While other available studies used relevant test animals, including the study that is the basis of the EcoSSL TRV, those studies used shorter exposure durations than the study by Ambrose et al. (1976), did not provide both NOAELs and LOAELs, or did not use the preferred exposure route (oral in food). The average weight of weanling rats decreased in the 1000-ppm nickel group, but did not decrease in the 0-, 250-, and 500-ppm exposure groups. because this study did not provide the information needed to develop daily doses, body weight and ingestion rate were assumed (see Table 15). The resulting nickel NOAEL TRV for mammals is 40 mg/kg-d, and the LOAEL is 80 mg/kg-d.

6.4.2.15 Selenium

Birds: The study by Stanley et al. (1996) used the longest exposure duration and was chosen as the study from which to derive the avian TRVs for selenium. In this study, 1-year-old breeding mallards are fed 0, 3.5, or 7 ppm selenium as selenium-DL-methionine in food on a dry-weight basis for 122 days. Hatching success was significantly reduced in the 7-ppm group (LOAEL), but not in the 3.5-ppm group (NOAEL), as compared to the control group (0 ppm group). Using a body weight of 1.043 kg (U.S. EPA 1993) and ingestion rate of 0.05 kg/d (estimated from omnivorous bird dry matter equation [Nagy 2001]) for the mallard, the resulting NOAEL and

LOAEL TRVs are 0.2 mg/kg/d and 0.4 mg/kg/d, respectively. The EPA EcoSSL TRV for selenium is based on a study with chickens (El-Begearmi and Combs 1982), which are not the preferred test species for wildlife TRV derivation.

Mammals: The mammalian TRVs for selenium were based on a rat study by Rosenfeld and Beath (1954). In this study, rats were exposed to 0, 1.5, 2.5, or 7.5 ppm of selenium as potassium selenate in drinking water for two generations. The treatment group exposed to 2.5 ppm showed no significant difference with regard to reproduction or number of young reared. However, the second-generation female progeny of this treatment group did show a 50 percent reduction in the number of young reared. Therefore, the NOAEL TRV was determined based on a dose of 1.5 ppm. Assuming a water intake rate of 0.046 L/day (based on the scaling function of Calder and Braun 1983) and an average body weight of 0.35 kg (U.S. EPA 1988), a NOAEL TRV of 0.20 mg/kg-day and a LOAEL TRV of 0.33 mg/kg-day were determined. The EPA EcoSSL NOAEL TRV is based on a study with pigs (Mahan and Moxon 1984), which are not a preferred test species for wildlife TRV derivation.

6.4.2.16 Silver

Birds: The EPA EcoSSL TRV for Ag for birds is a NOAEL of 2.02 mg/kg/d. EPA states that the NOAEL is the lowest LOAEL for growth and survival divided by 10. This NOAEL is based on a study by Jensen et al. (1974), in which turkey poults were fed 0, 100, 300, or 900 ppm Ag in food for four weeks. Another study in turkeys (Peterson et al. 1973) used relevant route of exposure and endpoints, but does not provide both a NOAEL and LOAEL and is not considered further in this TRV development process. Jensen et al. (1974) found that growth rates were depressed in the 900-ppm group, but were unaffected in the 300-ppm group. This study did not provided daily doses or information needed to calculate daily doses. The body weight and ingestion rate used to calculate the daily doses were assumed (Table 15), and the resulting Ag NOAEL is 6.8 mg/kg/d and the LOAEL is 21 mg/kg/d.

Mammals: The EPA EcoSSL TRV for Ag for mammals is a NOAEL of 6.02 mg/kg/d. EPA states that the NOAEL is the lowest LOAEL for growth and survival divided by 10. This NOAEL is based on a study by Van Vleet (1976), which used pigs and is not considered relevant in this TRV development process. EPA lists only one study (Shavlovski et al. 1995) with ecologically relevant endpoint and test species. In this study, rats are fed 0 or 50 mg silver acetate (75.2% Ag by molecular weight) in food/organism/d for 20 days during gestation. The weight of progeny was significantly affected at 50 mg/organisms/day (188 mg/kg/day). This is an unbounded chronic LOAEL; thus, a LOAEL-to-NOAEL factor of 0.1 is applied to the LOAEL to estimate a NOAEL. The resulting Ag NOAEL is 18.8 mg/kg/d, and the LOAEL is 188 mg/kg/d.

6.4.2.17 Thallium

Birds: EPA does not provide EcoSSL TRVs for birds, and there are few studies on the effects of thallium on birds. A study on ring-necked pheasant by Hudson et al. (1984) was used for this avian TRV derivation process, because very few studies exist. Hudson et al. (1984) found that 50% of the dosed animals died at a concentration of 23.7 mg of thallium per kg body weight. This was considered to be the LOAEL. The NOAEL was estimated from the LD_{50} by applying an uncertainty factor of 100 to the LD_{50}.

Mammals: EPA does not provide EcoSSL TRVs for mammals. However, there are sufficient studies on mammalian species to derive thallium TRVs for mammals. A study on rats by Formigli et al. (1986) was selected for this mammalian TRV derivation process, because this study used preferred toxicological endpoints. In the study by Formigli et al., groups of rats were dosed with thallium sulfide in water at 0 or 270 μg Tl/rat/d (0.74 mg/kg/d) for 60 days. Reduced sperm count and motility were observed in rats exposed to 0.74 mg/kg/d (LOAEL). The NOAEL was estimated from the LOAEL by dividing by 10; therefore, the NOAEL is 0.074 mg/kg/d.

6.4.2.18 Vanadium

Birds: The NOAEL TRV for birds was developed from a study by White and Dieter (1978). In this study, mallard ducks were dosed with 2.84, 10.36, and 110 ppm of vanadium (as vanadyl sulfate) in food for 12 weeks. The researchers observed endpoints such as mortality, body weight, and blood chemistry, and found that no adverse effects were observed at any of the dose levels. Therefore, a NOAEL of 11 mg/kg-day was calculated based on the dose of 110 mg/kg, a food ingestion rate of 121 g/day, and a body weight of 1.17 kg. A LOAEL TRV could not be calculated from this study, and no other studies were identified that could be used to derive a LOAEL. The EPA EcoSSL NOAEL TRV is based on a chicken study (Hill 1979). Chickens are not good surrogate species for mallard or other wildlife species, and when relevant studies on other more appropriate test species were available, chicken studies were not used for TRV development.

Mammals: The mammalian TRV for vanadium was developed based on a study by Domingo et al. (1986). In this investigation, rats were exposed to sodium metavanadate ($NaVO_3$) at three dose levels (5, 10, and 20 mg/kg-day at 41.78 percent vanadium) by oral intubation. Exposure started 60 days prior to gestation and continued through gestation, delivery, and lactation. Significant adverse effects (i.e., increased number of stillbirths per litter, decreased offspring size and weight) were observed at all dose levels. Therefore, the lowest dose (2.09 mg/kg-day vanadium by percentage of weight) was considered to be the chronic LOAEL. The NOAEL TRV for mammals was therefore determined by applying a 0.1 uncertainty factor to yield a value of 0.209 mg/kg-day.

6.4.2.19 Zinc

Birds: The avian TRV for zinc toxicity was based on a feeding study performed by Stahl et al. (1990). In this study, 24- or 56-week-old white leghorn hens were exposed to zinc sulfate in their diet from 28 mg/kg (control) to 2,000 mg/kg in a dehydrated corn and soybean meal diet. After continuous daily exposure until 68 weeks of age, no significant differences were noted in hen weight, feed consumed, egg production, egg fertility, egg hatchability, or progeny growth rates. Therefore, the NOAEL TRV is 130 mg/kg-day (calculated with a dietary concentration of 2,000 mg/kg, a measured intake rate of 0.06 kg dry weight/kg body weight, and assuming 10% moisture content of food). No LOAEL was reported.

Mammals: The NOAEL and LOAEL TRVs used to evaluate risks from zinc exposure in mammals were developed from a study by Schlicker and Cox (1968). In this investigation, adult female Sprague-Dawley rats were exposed to 2,000 and 4,000 mg/kg dry weight zinc oxide in their diets. Exposure commenced 21 days prior to mating and continued throughout gestation. Females exposed to 4,000 ppm exhibited increases in fetal resorption. No effect on reproduction (measured as percent resorption or difference in rate of fetal growth) was observed at 2,000 ppm. Based on an assumed body mass of 0.35 kg (U.S. EPA 1988) and a food ingestion rate of 0.028 kg/day, the LOAEL and NOAEL TRVs were calculated to be 160 and 320 mg/kg-day, respectively.

6.5 Risk Characterization

Risk characterization is the final phase of the risk assessment process and includes risk estimation and risk description (U.S. EPA 1997). In the risk estimation step of the BERA, risks posed to environmental receptors will be estimated by comparing the exposure measures or doses, which are developed in the exposure assessment, to the measures associated with toxicological effects, which are developed in the effects assessment. The risk description will provide information for interpreting the risk results. In accordance with EPA guidance (1997), a weight-of-evidence approach will be used to interpret the results of the Phase I ecological investigation and their implications for the assessment endpoints. The risk characterization will also identify uncertainties, assumptions, professional judgments, and qualifiers associated with the risk estimates.

6.5.1 Risk Estimation

The estimation of risks to ecological receptors will be based on an integration of all the lines of evidence from the exposure and effects assessments. For terrestrial and aquatic plants, terrestrial and aquatic benthic invertebrates, and for fish, this integration will entail comparison of measured CoPC concentrations in environmental media and/or tissue to literature effects levels. For avian and mammalian receptors, the modeled range of exposure (i.e., mean, 95% UCL, and maximum) will be based on the range of CoPC concentrations in environmental media and prey and the quantitative characteristics of the target receptor populations. For wildlife, the risks will be presented as Hazard Quotients (HQs). The method simply compares exposure concentrations or doses of CoPCs to LOAELs and NOAELs. For example,

$$HQ = Dose_{exposure} / Dose_{effects}$$

where:

$Dose_{exposure}$ = the dose to which an organism is exposed, and

$Dose_{effects}$ = the dose at or above which adverse effects may occur, or TRV.

HQs less than one indicate that the chemical is unlikely to cause adverse ecological effects. HQs above one indicate some potential for adverse ecological effects but do not necessarily signify unacceptable risk. Other pieces of information, such as sources of uncertainty and site-specific exposure data, will be weighed in the risk evaluation and the interpretation of the ecological significance of HQs. According to U.S. EPA (1997), "As certainty in the exposure concentrations and the NOAEL increase, there is greater confidence in the predictive value of the hazard quotient model, and unity (HQ = 1) becomes a more certain pass/fail decision point." Therefore, HQs will be determined by comparison to both the NOAEL and the LOAEL TRVs, where available, to bracket the risk estimates and reflect the range of uncertainty that exists regarding the potential for adverse effects. Because the NOAEL represents a body-weight-normalized daily intake rate of a chemical that did not elicit any adverse responses in the test organism, exceedance of this value does not necessarily imply that adverse effects would occur for ecological receptors. Exposure estimates that are below the NOAEL TRV identify conditions under which adverse ecological effects are unlikely to occur. The LOAEL is the minimum dose reported to elicit a statistically significant adverse effect in the test species in the pertinent laboratory study. Thus, an exposure rate in excess of the LOAEL TRV indicates some potential for adverse effects to an exposed individual or population.

For exposure estimates greater than the NOAEL TRV, but less than the LOAEL TRV, risk cannot be concluded definitively to be negligible, because the true effect threshold is not known, only that it lies somewhere between the NOAEL and LOAEL. Furthermore, because the test endpoints measure individual-level responses, there is considerable uncertainty regarding how these effects, if any, would translate to population-level effects. Therefore, these uncertainties will be assessed along with other lines of evidence, such as habitat quality, to interpret the ecological significance of HQs that exceed one and draw conclusions regarding ecological risk. The significance of the results of the risk characterization will be discussed in the final sections of the draft BERA—the uncertainty analysis, and in the summary and conclusions. The risks estimated for all various ecological receptors will be integrated and interpreted to evaluate their overall significance to the study area ecosystems, and to help identify what corrective measures, if any, may be required to reduce these risks.

6.5.2 Uncertainty Analysis

The risk characterization will include a detailed evaluation of sources of uncertainty and the effects of these uncertainties on conclusions about the extent and magnitude of risks. There are likely to be several major sources of uncertainty related to results of the risk assessment, which may include, but are not necessarily restricted to, those listed below:

- Evaluation of potential risks related to metals in water
  - Representativeness of sampling locations
  - Comparisons with water quality values
  - Uncertainty in correlating observed aquatic community responses with CoPC concentrations in water
  - Uncertainty in extrapolation of risks to aquatic populations.
- Evaluation of potential risks related to metals in sediment
  - Representativeness of sampling locations
  - Comparisons with sediment quality values
  - Uncertainty in correlating observed aquatic plant and benthic community responses with CoPC concentrations in sediment
  - Uncertainty in extrapolation of risks to aquatic plant and benthic invertebrate populations.
- Evaluation of potential risks related to metals in soil
  - Representativeness of sampling locations
  - Comparisons with soil toxicity benchmarks
  - Uncertainty in correlating observed terrestrial plant and soil fauna community responses with CoPC concentrations in soil.
  - Uncertainty in extrapolation of risks to terrestrial vegetation and soil fauna populations.

- Evaluation of potential risks to wildlife
  - Wildlife exposure estimates
  - Tissue-based effects levels
  - TRVs
  - Uncertainty in TRV extrapolation
  - Population-level uncertainty
  - Uncertainty in risk characterization.

Major sources of uncertainty and their effects on risk characterization conclusions will be discussed in detail in the uncertainty analysis.

7 Phase II Ecological Studies (2010)

The necessity for Phase II ecological studies will be determined following completion of the 2009 Phase I ecological site investigation and the draft BERA. If the draft BERA concludes that the data are adequate to assess risks for all pathways and receptors with sufficient accuracy, the BERA process will end there. However, if risks for certain pathways or receptors are too uncertain to inform risk management decisions, or if additional pathways or receptors are identified in Phase I, Phase II studies will be designed and conducted in the 2010 field season. This section provides an overview of what the Phase II ecological studies might include, based on current information. Details on these studies, if necessary, will be developed in a Phase II work plan and FSAP.

7.1 Selenium Effects in Wildlife Receptors

In the 2005 Supplemental ERA, selenium was determined to be a metal of concern for mallard, belted kingfisher, cliff swallow, and mink for exposures at Lower Lake and Upper Lake Marsh (Table 2). However, these conclusions were based on conservative food-chain modeling with limited site-specific, empirical exposure data. Selenium can cause significant effects to fish and aquatic dependent wildlife as a result of its ability to bioaccumulate in the aquatic food web. It is now understood that water concentrations are not predictive of whether selenium will bioaccumulate within a particular water body (Luoma et al. 1992). Also, accumulation of selenium is very site-specific, depending on factors such as the flow rate of the water, the amount and type of particulate matter, and the kinds of invertebrates that may be present. Selenium risk to birds can be predicted from measured concentrations in fish and invertebrates. To address concerns raised by EPA and FWS regarding potential effects to wildlife from selenium exposure at the site, the Phase I ecological investigation will provide data to assess risk to fish and higher-trophic-level birds and mammals from selenium exposure using food-chain models. If this approach cannot rule out risk from selenium in the aquatic environment, a more comprehensive selenium assessment will be conducted in the Phase II ecological investigation.

The Phase II selenium assessment will include an adaptation of the Selenium Assessment Protocol described by Lemly (2002), or similar approach. The Lemly (2002) protocol considers bioaccumulation of selenium up the food chain and potential reproductive impairment in birds and fish. This approach integrates biotic and abiotic cycling of selenium with site-specific exposure and concentration data. These data are combined to create hazard scores, which can be used to compare disparate sites or compare data over time. The focus on reproductive impairment provides a conservative approach by focusing on a sensitive endpoint.

The Lemly (2002) protocol relies on exposure data determined by selenium concentrations in fish eggs and bird eggs, as well as selenium in surface water, sediment, and benthic invertebrates. Eggs are an important component, because reproductive success is the most sensitive biological response to selenium toxicity in fish and birds. If some media are not available, for example bird eggs, a surrogate medium can be used in conjunction with available correction factors. Selenium concentrations from these various media are compared to hazard profiles, which are derived from laboratory and field studies that assessed toxic thresholds of selenium across a wide range of environmental conditions and habitats. A detailed description of the Phase II selenium assessment approach will be developed as part of the Phase II work plan, if necessary.

7.2 Wilson Ditch Investigation

The current understanding of Wilson Ditch is that it may not provide suitable habitat for aquatic receptors and/or wildlife, such as waterfowl. Surface water and sediment samples are the only media that will be sampled from Wilson Ditch during the Phase I ecological study. Data collected during the Phase I field sampling program and information from the habitat characterization will be used to estimate the potential for unacceptable risk to wildlife receptors that might forage in Wilson Ditch. If risk to ecological receptors from exposure to metals in Wilson Ditch cannot be concluded to be low to negligible in the draft BERA, and if it is determined that Wilson Ditch provides suitable habitat and is being used by receptors, additional sampling will be conducted as part of the Phase II ecological investigation. Phase II sampling in Wilson Ditch, if warranted, will include additional surface-water and sediment samples, as well as biota samples (similar to the Phase I sampling program for Prickly Pear

Creek). These data will be used to further assess risk to aquatic receptors, and will be incorporated into food-chain models to estimate risk to wildlife that may use the ditch for foraging. A detailed description of the Phase II Wilson Ditch investigation will be developed as part of the Phase II work plan, if necessary.

8 References

ACI. 2005. Phase I RCRA facility investigation site characterization report, East Helena Facility, July 2005. Asarco Consulting, Inc.

Ambrose, A.M., P.S. Larson, J.F. Borzelleca, and G.R. Hennigar, Jr. 1976. Long term toxicologic assessment of nickel in rats and dogs. J. Food Sci. Technol. 13:181–187.

al Ankari, A., H. Najib, and A. al Hozab. 1998. Yolk and serum cholesterol and production traits, as affected by incorporating a supraoptimal amount of copper in the diet of the leghorn hen. Br. Poult. Sci. 39(3):393–397.

Asarco. 2008. Addendum to interim measures work plan, East Helena facility former acid plant sediment drying area slurry wall monitoring. Operation, and maintenance report.

ASTM. 2007. E1706-05 standard test method for measuring the toxicity of sediment-associated contaminants with freshwater invertebrates. American Society for Testing and Materials.

Aulerich, R.J., R.K. Ringer, and S. Iwamoto. 1974. Effects of dietary mercury on mink. Arch. Environ. Contam. Toxicol. 2:43–51.

Aulerich, R.J., R.K. Ringer, M.R. Bleavins, and A. Napolitano. 1982. Effects of supplemental dietary copper on growth, reproductive performance and kit survival of standard dark mink and the acute toxicity of copper to mink. J. Anim. Sci. 55:337–343.

Azar, A., H.J. Trochimowicz, and M.E. Maxwell. 1973. Review of lead studies in animals carried out at Haskell Laboratory: Two-year feeding study and response to hemorrhage study. In: Environmental Health Aspects of Lead: Proceedings, International Symposium, D. Barth et al., Eds. Commission of European Communities. Pp. 199-210.

Beyer, W.N., and G.F. Fries. 2003. Toxicological significance of soil ingestion by wild and domestic animals. In: Handbook of ecotoxicology. Second edition. Lewis Publishers, Boca Raton, FL, pp. 151–166.

Beyer, W.N., E.E. Connor, and S. Gerould. 1994. Estimates of soil ingestion by wildlife. J. Wildl. Manage. 58:375–382.Borzelleca, J.F., L.W. Condie, Jr., and J.L. Egle, Jr. 1988. Short-term toxicity (one- and ten-day gavage) of barium chloride in male and female rats. J. Am. Coll. Toxicol. 7:675-685.

Cain, B.W., and E.A. Pafford. 1981. Effects of dietary nickel on survival and growth of mallard ducklings. Arch. Environ. Contam. Toxicol. 10(6): 737-745.

Calder, W.A., and E.J. Braun. 1983. Scaling of osmotic regulation in mammals and birds. Am. J. Physiol. 224:601–606.

Carriere, D., K. Fischer, D. Peakall, and P. Angehrn. 1986. Effects of dietary aluminum in combination with calcium and phosphorous on the ring dove (*Streptopelia risoria*). Water Air Soil Pollut. 30:757–764.

CCME. 2002. Canadian sediment quality guidelines for the protection of aquatic life: Summary tables. Updated. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

CH2M Hill 1987a. Remedial investigation of soils, vegetation, and livestock. EPA Work Assignment No. 68-8L30.0. May 1987.

CH2M Hill. 1987b. Assessment of the toxicity of arsenic, cadmium, lead, and zinc in soil, plants, and livestock in the Helena Valley of Montana. EPA Work Assignment No. 68-8L30.0. May 1987.

CH2M Hill. 1987c. Assessment of the toxicity of copper, mercury, selenium, silver, and thallium in soil and plants in the Helena Valley of Montana. EPA Work Assignment No. 68-8L30.0. May 1987.

Dieter, M.P., M.I. Luster, G.A. Boorman, C.W. Jameson, J.H. Dean, and J.W. Cox. 1983. Immunological and biochemical responses in mice treated with mercuric chloride. Toxicol. Appl. Pharmacol. 68:218–228.

Dietz, D.D., M.R. Elwell, W.E. Davis, Jr., and E.F. Meirhenry. 1992. Subchronic toxicity of barium chloride dehydrate administered to rats and mice in the drinking water. Fundam. Appl. Toxicol. 19:527-537.

Domingo, J.L., J.L. Paternain, J.M. Llobet, and J. Corbella. 1986. Effects of vanadium on reproduction, gestation, parturition and lactation in rats upon oral administration. Life Sci. 39:819–824.

Edens, F.W., and J.D. Garlich. 1983. Lead-induced egg production decrease in leghorn and Japanese quail hens. Poult. Sci. 62(9):1757-1763.

Edens, F.W., E. Benton, S.J. Bursian, and G.W. Morgan. 1976. Effect of dietary lead on reproductive performance in Japanese quail, *Coturnix coturnix japonica*. Toxicol. Appl. Pharmacol. 38:307–314.

Efroymson, R., M. Will, and G. Suter, II. 1997a. Toxicological benchmarks for contaminants of potential concern for effects on soil and litter invertebrates and heterotrophic processes: 1997 Revision. ES/ER/TM-126/R2. Oak Ridge National Laboratory, Oak Ridge, TN.

Efroymson, R., M. Will, G. Suter, II, and A. Wooten. 1997b. Toxicological benchmarks for screening contaminants of potential concern for effects on terrestrial plants: 1997 Revision. ES/ER/TM-85/R3. Oak Ridge National Laboratory, Oak Ridge, TN.

Eisler, R. 1988. Lead hazards to fish, wildlife, and invertebrates: A synoptic review. Biological Report 85(1.14). U.S. Fish and Wildlife Service.

El-Begearmi, M.M., and G.F. Combs Jr. 1982. Dietary effects on selenite toxicity in the chick. Poult. Sci. 61(4):770-776.

Formigli, L., R. Scelsi, P. Poggi, C. Gregotti, A. DiNucci, E. Sabbioni, L. Gottardi, and L. Manzo. 1986. Thallium-induced testicular toxicity in the rat. Environ. Res. 40:531–539.

Foster, S.D. 1999. The biological and physiological effects of excess copper in juvenile mallards (Anas platyrhynchos): An investigation of the toxicity of acid mine drainage in waterfowl. Masters Thesis. Colorado State University, Fort Collins, CO. 131 pp.
Gasaway, W.C., and I.O. Buss. 1972. Zinc toxicity in the mallard. J. Wildl. Manage. 36:1107-1117.

Haseltine, S.D., L. Sileo, D.J. Hoffman, and B.D. Mulhern. 1985. Effects of chromium on reproduction and growth in black ducks. Unpublished data (not seen, as cited in Sample et al. 1996).

Heinz, G. 1974. Effects of low dietary levels of methylmercury on mallard reproduction. Bull. Environ. Contam. Toxicol. 11(4):386-392.

Heinz, G. 1976a. Methylmercury: Second-year feeding effects on mallard reproduction and duckling behavior. J. Wildl. Manage. 40:82-90.

Heinz, G. 1976b. Methylmercury: Second-generation reproductive and behavioral effects on mallard ducks. J. Wildl. Manage 40(4):710-715.

Heinz, G. 1979. Methylmercury: Reproductive and behavioral effects on three generations of mallard ducks. J. Wildl. Manage 43(2):394-401.

Heinz, G.H., D.J. Hoffman, and L.G. Gold. 1989. Impaired reproduction of mallards fed an organic form of selenium. J. Wildl. Manage. 53(2):418–426.Hill, C.H. 1979. The effect of dietary protein levels on mineral toxicity in chicks. J. Nutr. 109(3):501-507.

Hill, E.F., and C.S. Schaffner. 1976. Sexual maturation and productivity of Japanese quail fed graded concentrations of mercuric chloride. Poult.Sci. 55:1449-1459.

Holcman, A., and V. Stibilj. 1997. Arsenic residues in eggs from laying hens fed with a diet containing arsenic (iii) oxide. Arch. Environ. Contam. Toxicol. 32(4):407-410.

Hudson, R.H., R.K. Tucker, and M.A. Haegele. 1984. Handbook of toxicity of pesticides to wildlife. U.S. Fish and Wildlife Service, Resour. Publ. 153. 90 p.

Hunter ESE. 1989. Comprehensive Endangerment Assessment. East Helena Smelter Site, Montana.

Hydrometrics, Inc. 1990. Comprehensive Remedial Investigation/Feasibility Study. Prepared for ASARCO, Inc. March 30, 1990.

Hydrometrics. 1999. Current conditions release/assessment, East Helena Facility, September 1998, Revised January 1999.

Hydrometrics, Inc. and Hunter/ESE. 1989. Process pond remedial investigation/feasibility study. Prepared for ASARCO, Inc. September 8, 1989.

Ingersoll, C.G., P.S. Haverland, E.L. Brunson, T.J. Canfield, F.J. Dwyer, C.E. Henke, N.E. Kemble, D.R. Mount, and R.G. Fox. 1996. Calculations and evaluation of sediment effect concentrations for the amphipod *Hyalella azteca* and the midge *Chironomus riparius*. J. Great Lakes Res. 22(3):602–623.

Jensen, L.S., R.P. Peterson, and L. Falen. 1974. Inducement of enlarged hearts and muscular dystrophy in turkey poults with dietary silver. Poult. Sci. 53(1):57-64.

Johnson, D. Jr., A.L. Mehring, Jr., and H.W. Titus. 1960. Tolerance of chickens for barium. Proc. Soc. Exp. Biol. Med. 104:436-438.

Kapustka, L.A., Clements, W.H., Ziccardi, L., Paquin, P.R., Sprenger, M., and D. Wall. 2004. Issue paper on the ecological effects of metals. Prepared for U.S. Environmental Protection Agency Contract #68-C-98-148. August 19, 2004. http://www.epa.gov/raf/publications/pdfs/ECOEFFECTSFINAL81904.PDF

Kern, M., M. Wisniewski, L. Cabell, and G. Audesirk. 2000. Inorganic lead and calcium interact positively in activation of calmodulin. Neurotoxicology 21:353—363.

Laskey, J.W., G.L. Rehnberg, J.F. Hein, and S.D. Carter. 1982. Effects of chronic manganese (Mn_3O_4) exposure on selected reproductive parameters in rats. J. Toxicol. Environ. Health 9:677–687.

Lemly, A.D. 2002. Selenium Assessment in Aquatic Ecosystems. A Guide for Hazard Evaluation and Water Quality Criteria. Springer.

Long, E.R., D.D. MacDonald, S.L. Smith, and F.D. Calder. 1995. Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. Environ. Manage. 19:81–97.

Luoma, S.N., C. Johns, N.S. Fisher, et al. 1992. Determination of selenium bioavailability to a benthic bivalve from particulate and solute pathways. Environ. Sci. Technol. 26:485–491.

MacDonald, D.D., C.G. Ingersoll, and T.A. Berger. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Arch. Environ. Contam. Toxicology 39:20–31.

Mahan, D.C., and A.L. Moxon. 1984. Effect of inorganic selenium supplementation on selenosis in postweaning swine. J. Animal Sci. 58(5):1216-1221.

McCarty, J.P. 1995. Effects of Short-Term Changes in Environmental Conditions on the Foraging Ecology and Reproductive Success of Tree Swallows, Tachycineta bicolor. Thesis (Ph.D.)--Cornell University

MDEQ. 2008. Circular DEQ-7. Montana Numeric Water Quality Standards. Montana Department of Environmental Quality. Planning, Prevention, and Assistance Division – Water.

MNHP. 2009. Species of Concern Report for Lewis and Clark County. Montana Natural Heritage Program. Accessed June 16, 2009 at http://mtnhp.org/SpeciesOfConcern/.

Montana Water Trust. 2008. Prickly Pear Creek website. Accessed June 20, 2009 at http://www.montanawatertrust.org/watersheds/pricklypearcreek.html.

Nagy, K.A. 1987. Field metabolic rate and food requirement scaling in mammals and birds. Ecol. Monogr. 57(2):111–128.

Nagy, K.A. 2001. Food requirements of wild animals: Predictive equations for free-living mammals, reptiles, and birds. Nutr. Abstr. Rev. Series B 71:21R-31R.

Nation, J.R., A.E. Bourgeois, D.E. Clark, and M.F. Hare. 1983. The effects of chronic cobalt exposure on behavior and metallothionein levels in the adult rat. Neurobehav. Toxicol. Teratol. 5(1):9-15.

Neiger, R.D., and G.D. Osweiler. 1989. Effect of subacute low level dietary sodium arsenite on dogs. Fund. Appl. Toxicol. 13:439-451.

Nemec, M.D., J.F. Holson, C.H. Farr, and R.D. Hood. 1998. Developmental toxicity assessment of arsenic acid in mice and rabbits. Reprod. Toxicol. 12(6):647-658.

Ondreicka, R., E. Ginter, and J. Kortus. 1966. Chronic toxicity of aluminium in rats and mice and its effects on phosphorus metabolism. Brit. J. Ind. Med. 23:305–312.

Pattee, O.H. 1984. Eggshell thickness and reproduction in American kestrels exposed to chronic dietary lead. Arch. Environ. Contam. Toxicol. 13:29-34.

Paulov, S. 1971. Changes of growth and of serum proteins in ducklings intoxicated with cobalt. Nutr. Metab. 13(1):66-70.

Peterson, R.P., L.S. Jensen, and P.C. Harrison. 1973. Effect of silver-induced enlarged hearts during the first four weeks of life on subsequent performance of turkeys. Avian Dis. 17(4):802-806.

ProUCL 4.0. 2007. A statistical software. National Exposure Research Lab, Las Vegas, NV. April.

Rosenfeld, I., and O.A. Beath. 1954. Effect of selenium on reproduction in rats. Proc. Soc. Exper. Biol. Med. 87(2):295–297.

Rossi, F., R. Acampora, C. Vacca, S. Maione, M.G. Matera, R. Servodio, and E. Marmo. 1987. Prenatal and postnatal antimony exposure in rats: Effect on vasomotor reactivity development of pups. Teratog. Carcinog. Mutagen. 7(5):491-496.

Sample, B.E., D.M. Opresko, and G.W. Suter. 1996. Toxicological benchmarks for wildlife: 1996 revision. ES/ER/TM-86/RS. Prepared for the U.S. Department of Energy, Office of Environmental Management. Oak Ridge National Laboratory, Risk Assessment Program, Health Sciences Research Division, Oak Ridge, TN.

Schlicker, S.A., and D.H. Cox. 1968. Maternal dietary zinc, and development and zinc, iron, and copper content of the rat fetus. J. Nutr. 95:287–294.

Schroeder, H.A., and M. Mitchener. 1975. Life-term studies in rats. Effects of aluminum, barium, beryllium, and tungsten. J. Nutr. 105(4): 421-7

Shavlovski, M.M., N.A. Chebotar, L.A. Konopistseva, E.T. Zakharova, A.M. Kachourin, V.B. Vassiliev, and V.S. Gaitskhoki. 1995. Embryotoxicity of silver ions is diminished by ceruloplasmin—Further evidence for its role in the transport of copper. Biometals 8(2):122-128.

Singh, A., and A.K. Singh. 2007. ProUCL Version 4.0 Technical Guide. EPA/600/R-07/041. April.

Shellenberger, T.E.. 1978. A multi-generation toxicity evaluation of p,p'-DDT and dieldrin with Japanese quail. I. Effects on growth and reproduction. Drug Chem. Toxicol. 1(2):137–146.

Silva, M., and J.A. Downing. 1995. CRC handbook of mammalian body masses. CRC Press, Boca Raton, FL.

Stahl, J.L., J.L. Gregor, and M.E. Cook. 1990. Breeding-hen and progeny performance when hens are fed excessive dietary zinc. Poult. Sci. 69:259–263.

Stanley Jr., T.R., J.W. Spann, G.J. Smith, and R. Rosscoe. 1994. Main and interactive effects of arsenic and selenium on mallard reproduction and duckling growth and survival. Arch. Environ. Contam. Toxicol. 26:444–451.

Stanley, T.R. Jr., G.J. Smith, D.J. Hoffman, G.H. Heinz, and R. Rosscoe. 1996. Effects of boron and selenium on mallard reproduction and duckling growth and survival. Environ. Toxicol. Chem. 15(7):1124-1132.

Sutou, S., K. Yamamoto, H. Sendota, and M. Sugiyama. 1980. Toxicity, fertility, teratogenicity, and dominant lethal tests in rats administered cadmium subchronically. I. Fertility, teratogenicity, and dominant lethal tests. Ecotoxicol. Environ. Saf. 4(1):51-56.

Terres, J. K. 1980. The Audubon Society encyclopedia of North American birds. Alfred A. Knopf, New York, NY.

U.S. EPA. 1988. Recommendations for and documentation of biological values for use in risk assessment. EPA/600/6-87/008. U.S. Environmental Protection Agency, Office of Research and Development, Cincinnati, OH.

U.S. EPA. 1989. Risk assessment guidance for Superfund (RAGS): Volume 1 – Human Health Evaluation Manual (Part A), Interim Final. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC.

U.S. EPA. 1992. Supplemental guidance to RAGS: Calculating the concentration term. Publication 9285.7-081. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, D.C.

U.S. EPA. 1993. Wildlife exposure factors handbook. Volume I of II. EPA/600/R-93/187a. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC.

U.S. EPA. 1993. Wildlife exposure factors handbook. Volume II of II: Food ingestion factors. EPA/600/P-95/002Fb. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC.

U.S. EPA. 1994. Selecting and using reference information in Superfund ecological risk assessments. ECO Update. EPA 540-F-94-050. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC.

U.S. EPA. 1996. Calculation and evaluation of sediment effect concentrations for the amphipod *Hyalella azteca* and the midge *Chironomus riparius*. EPA 905/R-96-008. U.S. Environmental Protection Agency, Great Lakes National Program Office, Chicago, IL.

U.S. EPA. 1997. Ecological risk assessment guidance for Superfund: Process for designing and conducting ecological risk assessments. Interim Final. U.S. Environmental Protection Agency, Environmental Response Team, Edison, NJ. EPA 540-R-97-006.

U.S. EPA. 1998. Guidelines for Ecological Risk Assessment. EPA/630/R-95/002F. Risk Assessment Forum.

U.S. EPA. 1999. Ecological Risk Assessment and Risk Management Principles for Superfund. Final guidance from Stephen Luftig, Director, Office of Emergency and Remedial Response.

U.S. EPA (2000) tox test guidelines

U.S. EPA. 2002. Calculating upper confidence limits for exposure point concentrations at hazardous waste sites. OSWER 9285.6-10. U.S. Environmental Protection Agency. December.

U.S. EPA. 2005a. Ecological soil screening levels. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response.

U.S. EPA. 2005b. Supplemental Ecological Risk Assessment for the East Helena Smelter Site, Montana.

U.S. EPA. 2006. Data quality assessment: statistical methods for practitioners. EPA QA/G-9S. EPA/240/B-06/003. Office of Environmental Information, Washington, D.C.

U.S. FWS. 1997. . Biological indices of lead exposure in relation to heavy metal residues in sediment and biota from Prickly Pear Creek and Lake Helena, Montana. USFWS Region 6 Contaminants Program. R6/214H/97.

U.S. FWS. 2006. Endangered, threatened, proposed, and candidate species. Montana counties. U.S. Department of Interior. U.S. Fish and Wildlife Service. Montana Field Office. Helena, MT.

Van Vleet, J.F. 1976. Induction of lesions of selenium vitamin E deficiency in pigs fed silver. Am. J. Vet. Res. 37(12):1415-1420.

Verschuuren, H.G., R. Kroes, and E.M. den Tonkelaar. 1976. Toxicity of methylmercury chloride in rats. II. Reproduction study. Toxicology 6:97-106.

Vohra, P., and Kratzer, F.H. 1968. Zinc, copper and manganese toxicities in turkey poults and their alleviation by EDTA. Poult. Sci. 47:699.

Vos, J.G., H.L. Van Der Mass, A. Musch, and E. Ram. 1971. Toxicity of hexachlorobenzene in Japanese quail with special reference to prophyria, liver damage, reproduction, and tissue residues. Toxicol. Appl. Pharmacol. 18:944-957.

White, D.H., and M.P. Dieter. 1978. Effects of dietary vanadium in mallard ducks. J. Toxicol. Environ. Health. 4:43–50.

White, D.H., and M.T. Finley. 1978. Uptake and retention of dietary cadmium in mallard ducks. Environ. Res. 17(1):53-59.

Yuhas, E.M., R.C. Schnell, and T.S. Miya. 1979. Dose-related alterations in growth and mineral disposition by chronic oral cadmium administration in the male rat. Toxicol. 12(1):19-29.

Zahid, Z.R., Z.S. Al Hakkak, A.H.H. Kadhim, E.A. Elias, and I.S. Al Jumaily. 1990. Comparative effects of trivalent and hexavalent chromium on spermatogenesis of the mouse. Toxicol. Environ. Chem. 25:131-136.

Figures

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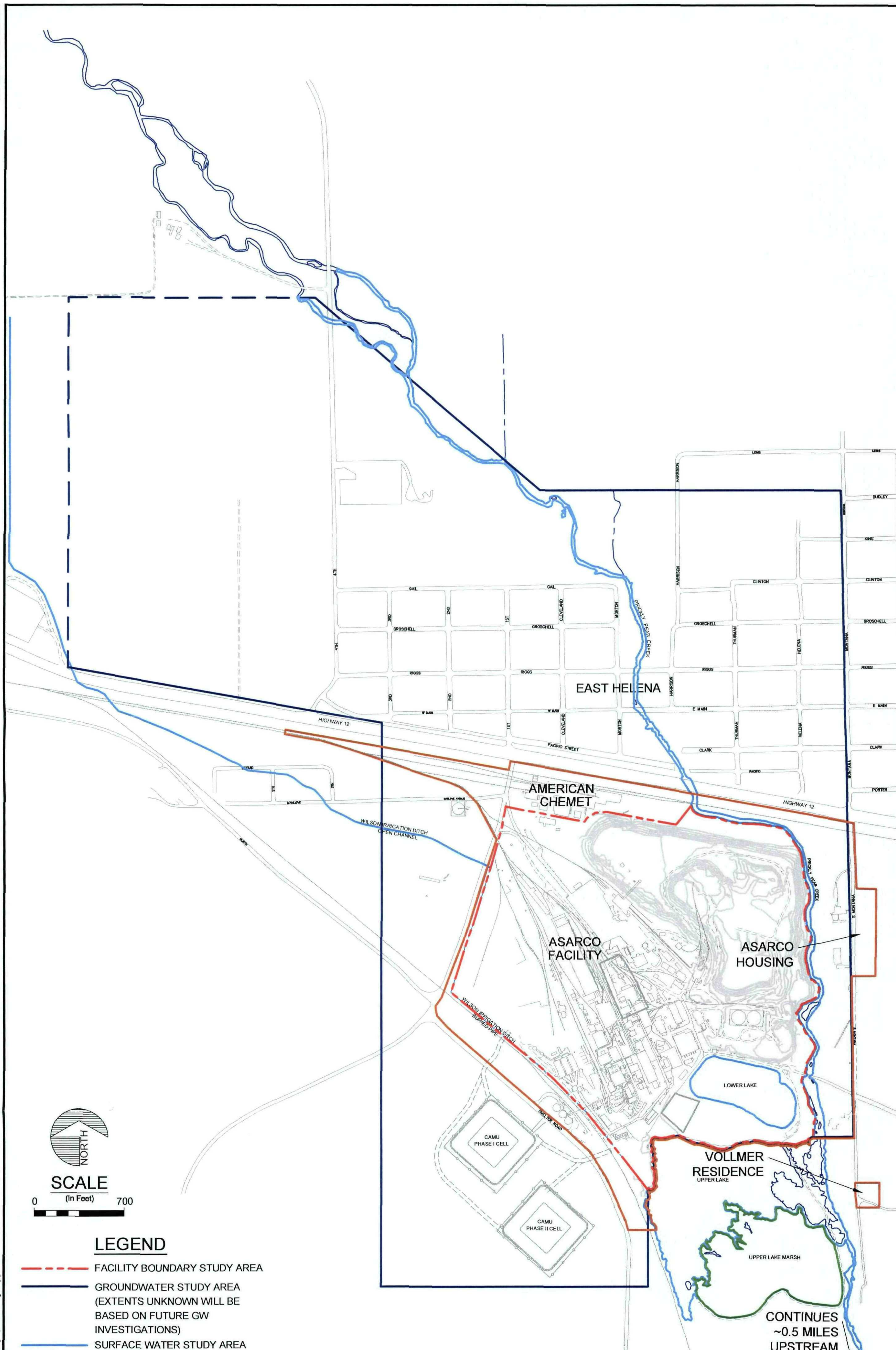

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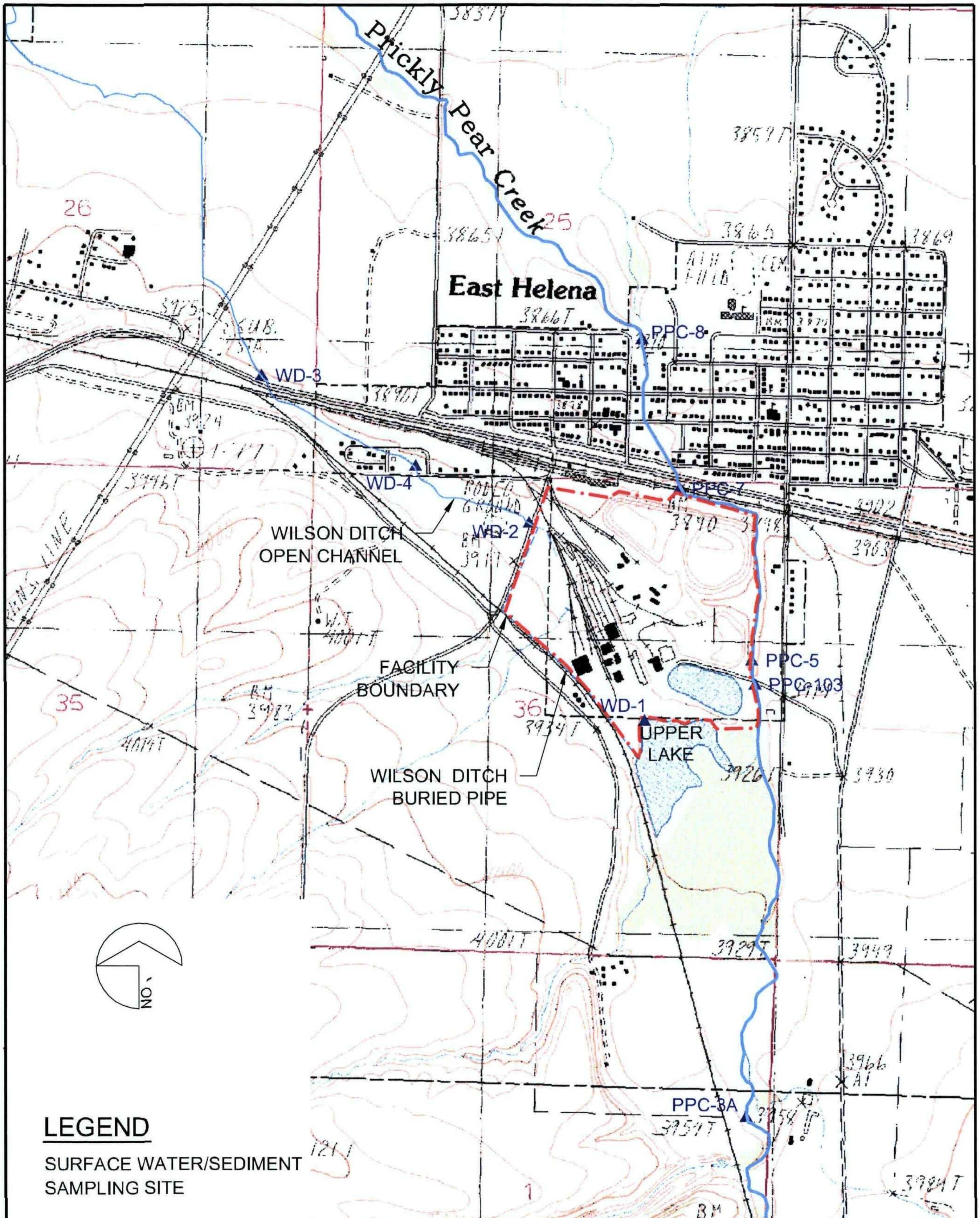
BASELINE ECOLOGICAL RISK ASSESSMENT WORK PLAN	SITE LOCATION MAP	FIGURE 1



BASELINE ECOLOGICAL RISK ASSESSMENT WORK PLAN	SURFACE WATER MONITORING SITES	FIGURE 2

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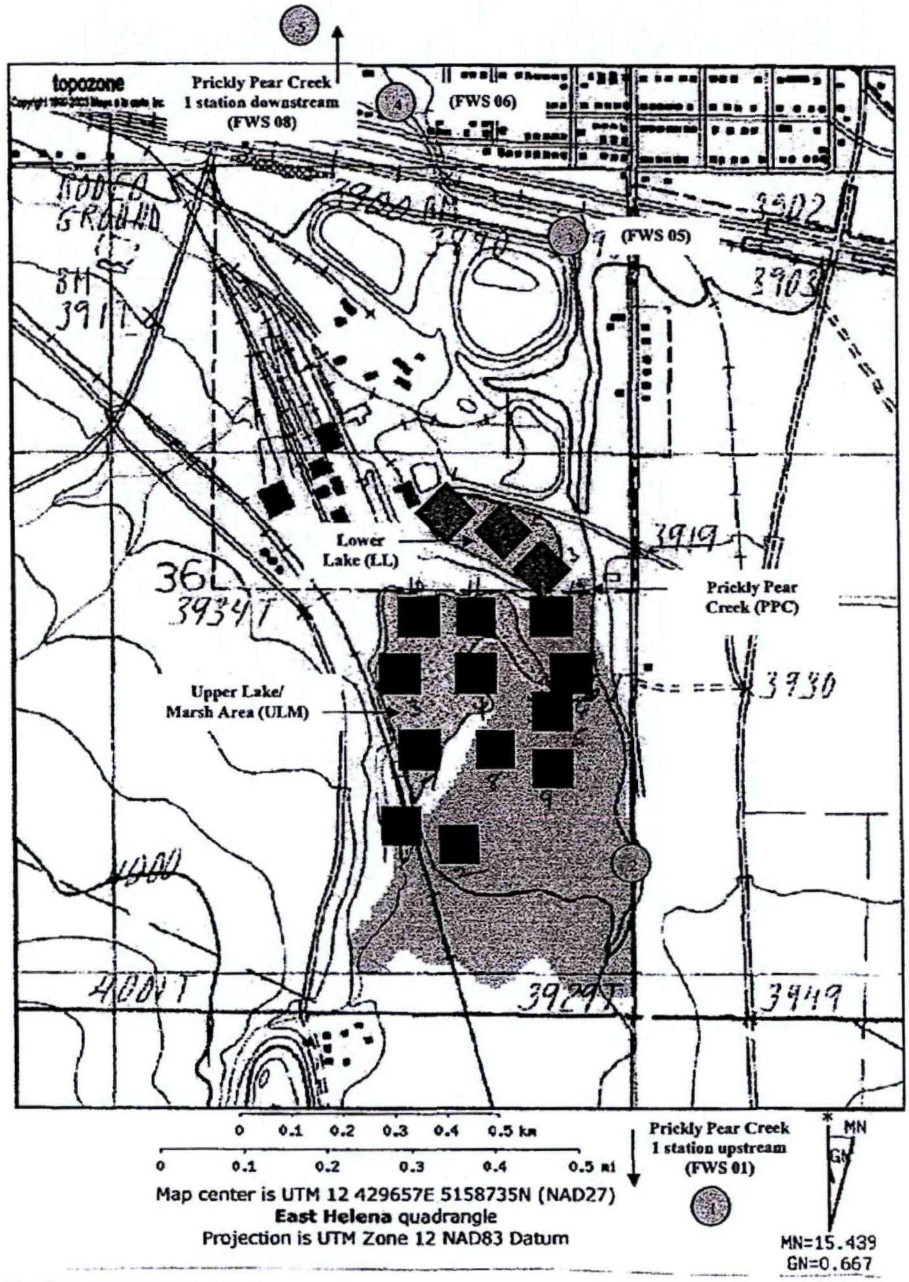
Figure 3-1 (Part A)
Sampling Locations for the Fall 2003 Ecological Field Investigation



Map Source: www.topozone.com
Prickly Pear Creek stations are also identified with their corresponding USFWS (1997) sampling location #

■ = Upper Lake/ Marsh Area (ULM) ◆ = Lower Lake (LL) ◎ = Prickly Pear Creek (PPC)
[symbols outlined in red indicate sediment toxicity tests were conducted for this location]

Source: U.S. EPA (2005b)

Figure 3. Surface water and sediment sampling locations for the Supplemental Ecological Risk Assessment.

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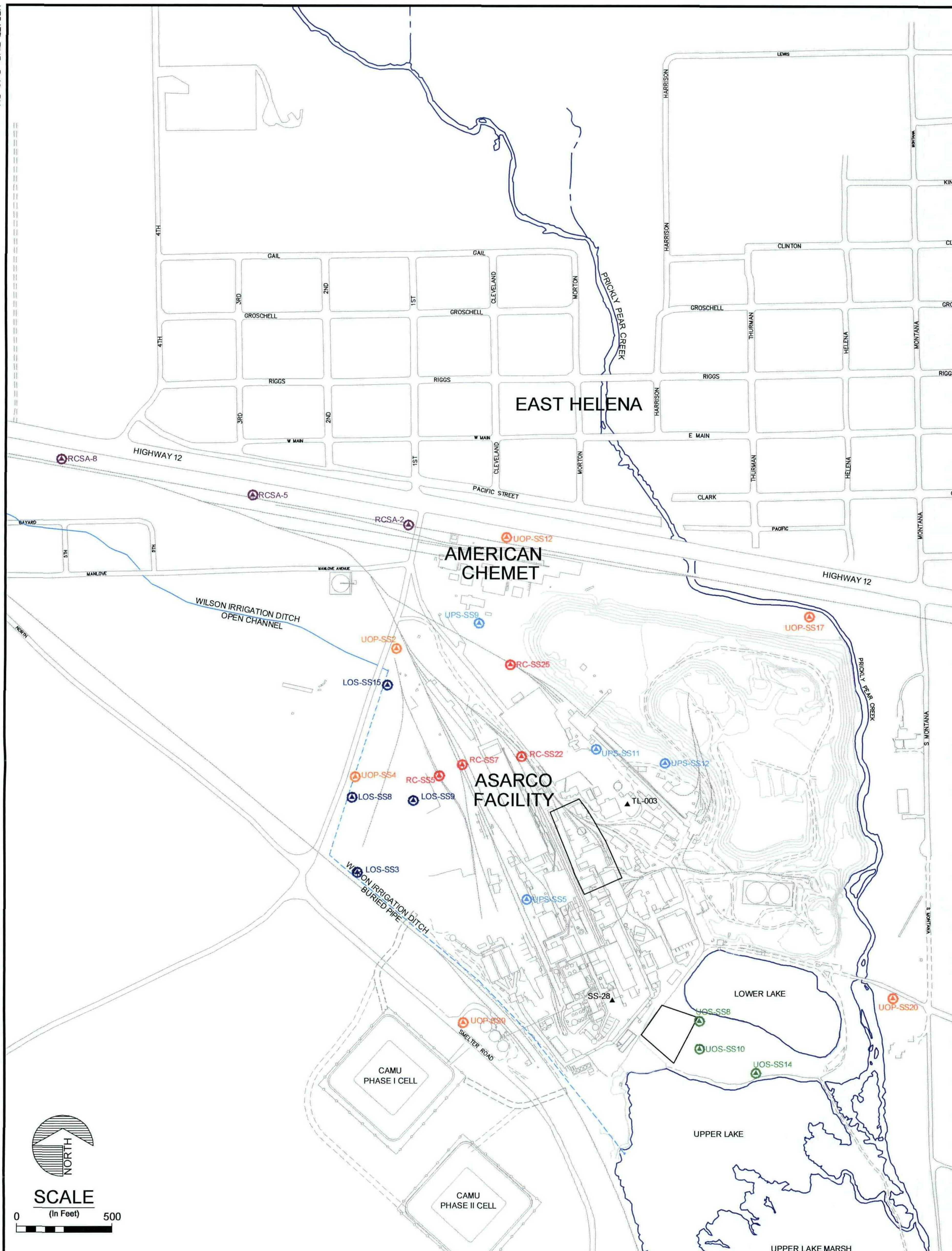

LEGEND

PHASE II RFI SOIL SAMPLE LOCATIONS BY AREA:

- UOP-SS4 PLANT PERIMETER SAMPLE
- UOS-SS10 TITO PARK SAMPLE
- LOS-SS8 LOWER ORE STORAGE AREA SAMPLE
- RCSA-5 RAIL CAR STAGING AREA SAMPLE
- RC-SS7 FORMER SITE RAIL CORRIDORS SAMPLE
- UPS-SS5 MISC. UNPAVED AREAS SAMPLE
- DH-56 SLAG PILE SAMPLE
- TL-003 ACID PLANT SAMPLE
- SS-28 THORNOCK LAKE SAMPLE

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BASELINE ECOLOGICAL RISK ASSESSMENT WORK PLAN	PLANT SITE AND SURROUNDING AREA SOIL SAMPLE LOCATIONS	FIGURE 4

Source: Aerial photograph from USGS NAIP (2008).

Figure 5. Aerial photo of the site

Exponent®

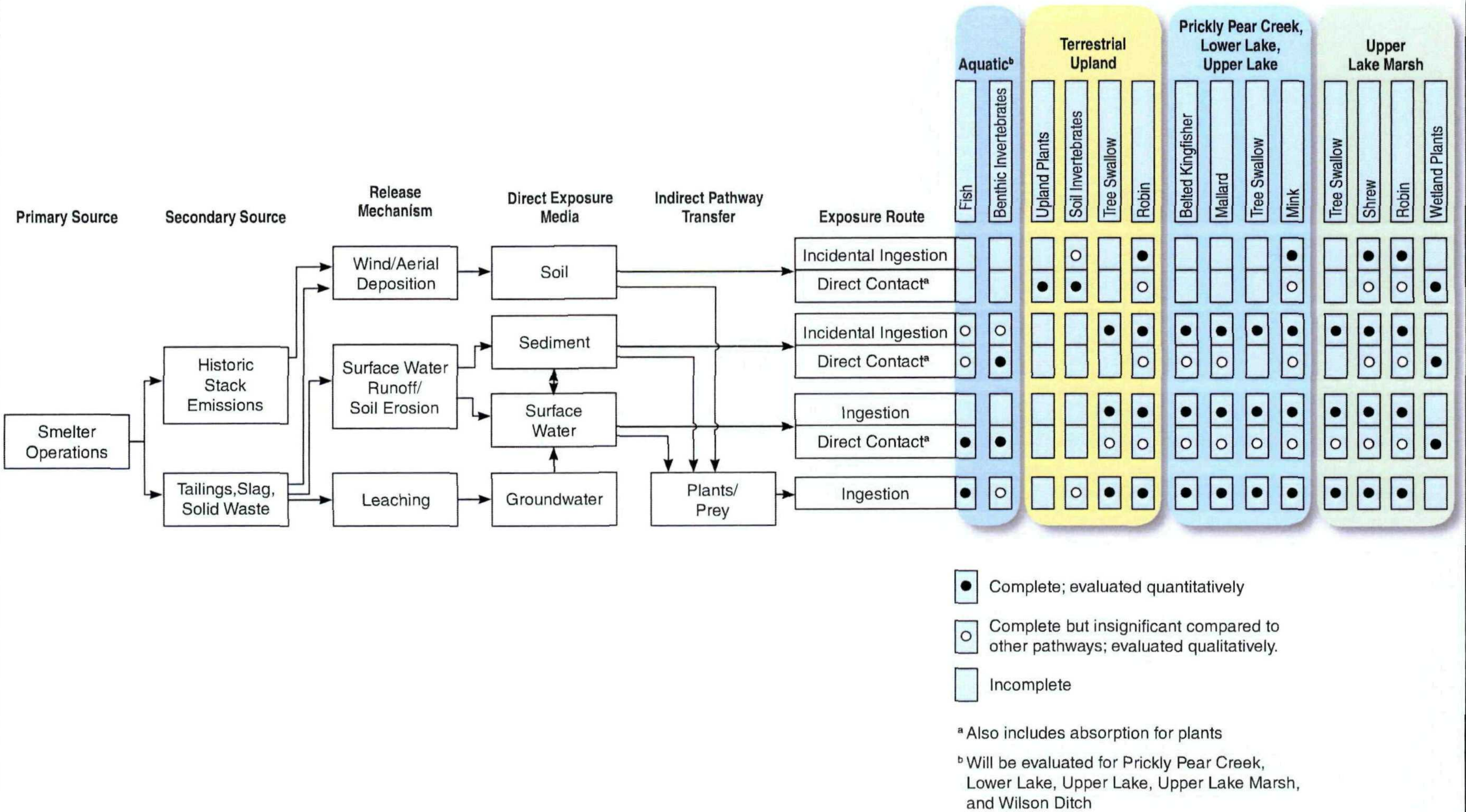

Figure 6. Preliminary conceptual site model

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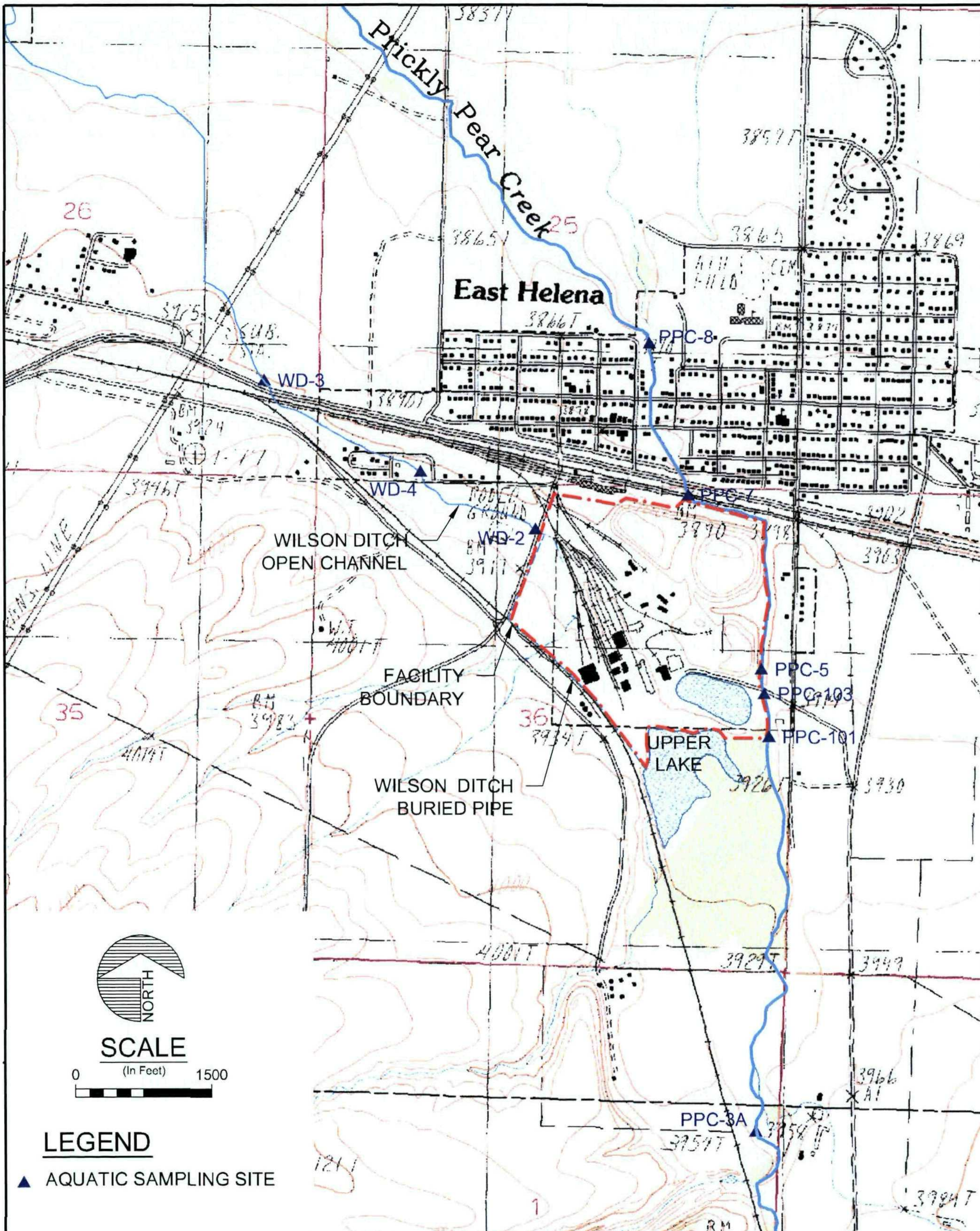

BASELINE ECOLOGICAL RISK ASSESSMENT WORK PLAN	PHASE I BERA AQUATIC SAMPLING LOCATIONS FOR PRICKLY PEAR CREEK AND WILSON DITCH	FIGURE 7

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BASELINE ECOLOGICAL RISK ASSESSMENT WORK PLAN

LOWER LAKE, UPPER LAKE, AND UPPER MARSH SOIL, SEDIMENT AND SURFACE WATER SAMPLING LOCATIONS

FIGURE
8

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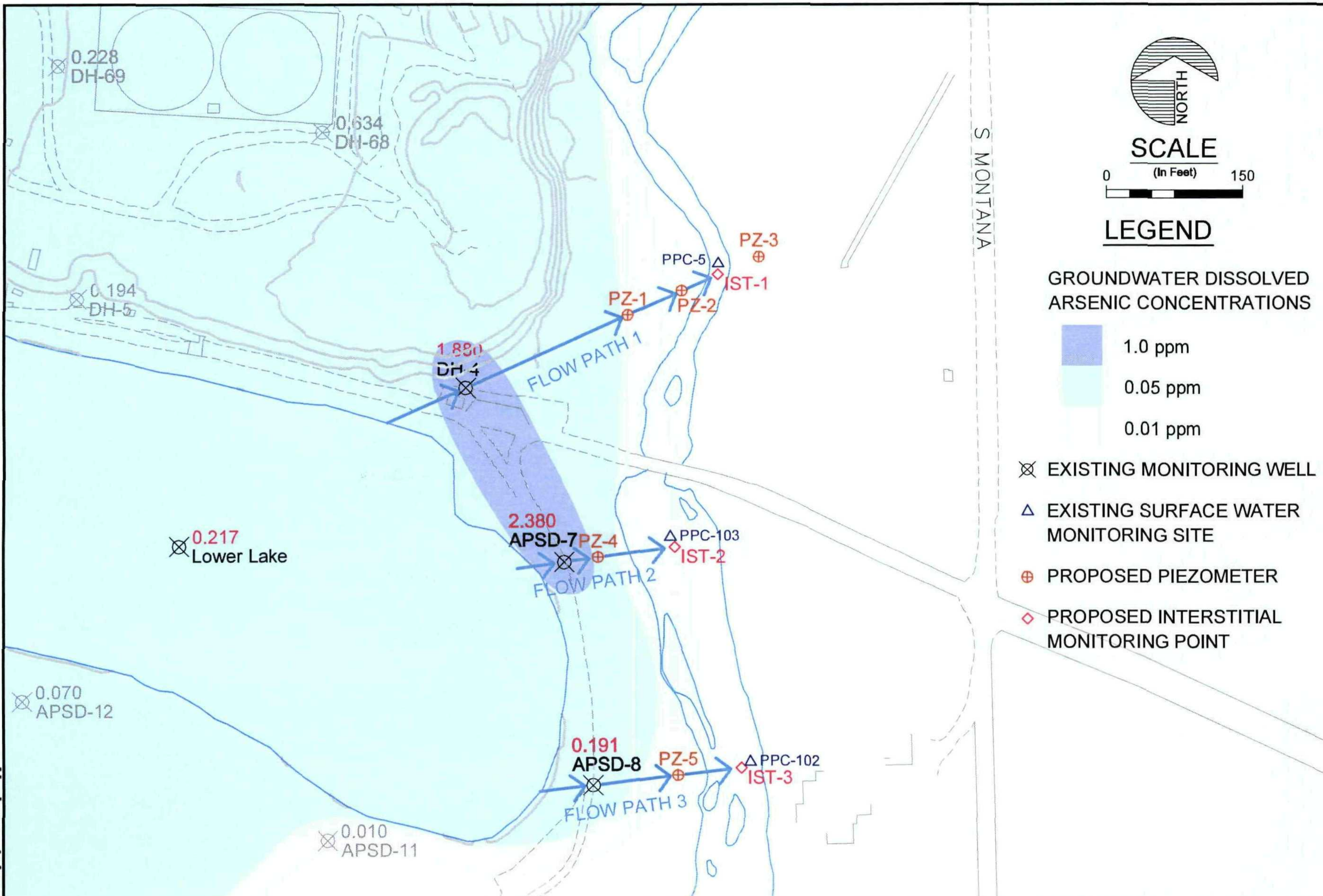

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BASELINE ECOLOGICAL RISK ASSESSMENT WORK PLAN	GENERAL GROUNDWATER/SURFACE WATER FLOW PATHS AND PROPOSED MONITORING POINTS	FIGURE 9

Tables

Table 1. Summary of data from previous investigations

Investigation	Media Analyzed	Locations	Analyses
Remedial Investigation, CH2MHill 1987	Soil (0-4", 4-8", 8-15", 15-30")	157 locations on site and in Helena Valley	Metals
	Plant tissue (grass, wheat, grain)	58 locations on site and in Helena Valley	
	Cattle blood and hair	8 site herds and 1 reference herd	
Process Pond RI/FS, Hydrometrics and Hunter ESE 1989	Surface Water	Lower Lake, Prickly Pear Creek, Wilson Ditch	Metals
	Sediment	Prickly Pear Creek, Wilson Ditch	
Comprehensive RI/FS, Hydrometrics, Roy F. Weston, Hunter ESE 1990	Surface Water	Irrigation Ditches, Prickly Pear Creek, Upper Lake	Metals
	Sediment	Prickly Pear Creek, Upper Lake, Wilson Ditch	
	Fish	Lake Helena, Prickly Pear Creek	
	Soil	Site and Helena Valley	
	Groundwater	Prickly Pear Creek, Upland	
	Vegetation	Helena Valley	
	Cattle	Helena Valley	
	Waterfowl	Literature Review	
Biological Indices of Lead Exposure in Relation to Heavy Metal Residues in Sediment and Biota from Prickly Pear Creek and Lake Helena, USFWS 1997	Sediment	Prickly Pear Creek	Metals
	Benthic Invertebrate	Prickly Pear Creek	
	Fish	Prickly Pear Creek	Tissue: Metals; Blood: ALAD Activity, ZPP Activity, Hemoglobin
	Mallard	Lake Helena and Canyon Ferry Reservoir	Blood: ALAD Activity, ZPP Activity, Hemoglobin
Supplemental Ecological Risk Assessment for the East Helena Smelter Site, Montana, USEPA 2005	Surface Water	Canyon Ferry Reservoir, Lower Lake, Prickly Pear Creek, Upper Lake/Marsh Area	Metals
	Sediment	Canyon Ferry Reservoir, Lower Lake, Prickly Pear Creek, Upper Lake/Marsh Area	Metals
	Sediment Toxicity	Canyon Ferry Reservoir, Lower Lake, Upper Lake/Marsh Area	Toxicity
	Sediment Porewater	Canyon Ferry Reservoir, Lower Lake, Prickly Pear Creek, Upper Lake/Marsh Area	Metals
	Benthic Invertebrates	Canyon Ferry Reservoir, Upper Lake/Marsh Area	Metals
	Benthic Invertebrate Community	Canyon Ferry Reservoir, Prickly Pear Creek, Upper Lake/Marsh Area	Community Assemblage
	Aquatic Plants/Algae	Canyon Ferry Reservoir, Upper Lake/Marsh Area	Metals
	Fish	Canyon Ferry Reservoir, Upper Lake/Marsh Area	Metals

Table 2. Primary drivers of predicted wildlife risks (modified from U.S. EPA 2005b)

Receptor/Surrogate Species	Metals of Concern	Exposure Areas	Primary Risk Drivers: Onsite Lakes & Marsh Areas			Primary Risk Drivers: Prickly Pear Creek		
			Dietary Items	Sediment	Surfacewater	Dietary Items	Sediment	Surfacewater
Waterfowl: Mallard	Lead	ULM, LL, PPC	□	■		■	□	
	Copper	ULM, LL, PPC	■	□		■		
	Cadmium	LL, ULM	□	■				
	Selenium	LL		■				
	Zinc	**PPC, ULM, LL**	□	■		■		
	Arsenic	LL, PPC		■				
Piscivorous birds: Belted Kingfisher	Lead	ULM, LL, PPC	□	■		■		
	Copper	ULM, LL	■	□				
	Cadmium	LL		■				
	Zinc	ULM	■					
	Selenium	LL		■				
	Mercury	ULM	■					
Insectivorous birds: Cliff Swallow	Lead	LL, ULM, PPC	□	■		□	■	
	Copper	ULM, LL, PPC	■	□		■	□	
	Cadmium	LL, ULM, PPC	□	■		■		
	Selenium	LL, ULM		■				
	Arsenic	LL, ULM, PPC		■				
	Zinc	ULM, PPC, LL	□	■		■	□	
	Mercury	ULM, LL	Not Evaluated	■				
	Manganese	PPC					■	
Piscivorous mammals: Mink	Antimony	LL	Not Evaluated	■				
	Arsenic	LL		■				
	Selenium	LL		■				
	Lead	ULM, LL		■				
	Thallium	LL	Not Evaluated	■				
	Zinc	ULM, PPC	■					
	Cadmium	LL		■				

Notes:

■ - Primary Contributor
□ - Secondary Contributor
LL - Lower Lake
PPC - Prickly Pear Creek
ULM - Upper Lake/Marsh Area

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Table 3. Surface-water data screening

	Surface Water Screening		Reference							Lower Lake						
Chemical	Acute	Chronic	Mean	Max	CFR_1 2003	CFR_2 2003	PPC_1 2003	PPC-3A 10/24/08	PPC-3A 04/30/08	Mean	Max	LL_1 2003	LL_2 2003	LL_3 2003	Lower Lake 10/24/08	Lower Lake 04/30/08
Dissolved metals (ug/L)																
Aluminum	750	87	88.0	102	100 U	102	100 U		50 U	87.5 U	100 U	100 U	100 U	100 U		50 U
Antimony			17.7	30 U	30 U	8.3	30 U		2.5 U	371	428	393	417	428		245
Arsenic			8.6	16.4	12.3	16.4	7.5 U	4	3	178	217	200	216	214	217	41
Barium			80.1	100 U	80.6	89.9	100 U		50 U	43.6	50 U	40	41.5	42.8		50 U
Beryllium			2.0 U	2.5 U	2.5 U	2.5 U	2.5 U		0.5 U	2.0 U	2.5 U	2.5 U	2.5 U	2.5 U		0.5 U
Cadmium			0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	4.7	6.9	6.9	6.6	6.8	1	2
Chromium			2.0	5 U	1.2	1.1	5 U		0.5 U	2.8	5 U	0.84	5 U	5 U		0.5 U
Cobalt			20.0 U	25 U	25 U	25 U	25 U		5 U	20.0 U	25 U	25 U	25 U	25 U		5 U
Copper			6.5	12.5 U	12.5 U	3.6	12.5 U	2 U	2 U	16.6	21.3	20.2	20.7	21.3	10	11
Iron			73.7	90	88	50 U	70.7	70	90	99.6	172	122	114	172	50	40
Lead			4.0 U	5 U	5 U	5 U	5 U	2.5 U	2.5 U	14.7	23.6	17.5	23.6	22.7	7	2.5 U
Manganese			17.9	30	7.5 U	7.5 U	14.6	30	30	174	207	199	204	207	130	130
Mercury			3.0 U	3.0 U					3 U	3.0 U	3.0 U					3 U
Nickel			16.3 U	20.0 U	20 U	20 U	20 U		5 U	4.0	5.0 U	2.8	3.7	4.4		5 U
Selenium			10.4	17.5 U	13.7	15.8	17.5 U	2.5 U	2.5 U	45.0	52.3	52.3	50.5	49.3	39	34
Silver			2.0	2.5 U	1.5				2.5 U	2.4	5.0 U	1.4	5 U	0.72		2.5 U
Thallium			9.6 U	12.5 U	12.5 U	12.5 U	12.5 U		1 U	72.1	73	72.9	71	71.4		73
Vanadium			6.0	9.6	7.4	9.6	2		5 U	20.0 U	25 U	25 U	25 U	25 U		5 U
Zinc			76.8	176	63.6	64.6	176	50	30	57.6	103	70.1	84.8	103	10 U	20
Hardness			127	180	144	180	57			199	207	190	200	207		
Total metals (ug/L)																
Aluminum			3213	6880	6880	5770	100 U		100	87.5 U	100 U	100 U	100 U	100 U		50 U
Antimony			12.6	30	6.9	30 U	10.9		2.5 U	374	437	375	423	437		260
Arsenic	340	150	8.4	14.8	14.8	11.5	7.5 U	4	4	202	243	221	239	242	243	67
Barium			98.5	125	125	119	100 U		50 U	43.9	50 U	38.3	43.4	43.9		50 U
Beryllium			1.0	2.5	0.52	0.43	2.5 U		0.5 U	2.0 U	2.5 U	2.5 U	2.5 U	2.5 U		0.5 U
Cadmium	2.1	0.27	0.44	0.52	0.17	0.52	0.5 U	0.5 U	0.5 U	6.5	8.9	8.2	8.3	8.9	3	4
Chromium	16	11	4.4	6.5	6.5	5.7	5 U		0.5 U	0.77	1.0	1	0.67	0.9		0.5 U
Cobalt			8.8	25.0	2.2	2.1	25 U		5 U	20.0 U	25.0 U	25 U	25 U	25 U		5 U
Copper	14.0	9.3	5.4	10.8	7.5	10.8	4.5	2 U	2 U	23.9	31.8	26.8	30.1	31.8	12	19
Iron		1000	2370	5760	5760	5370	191	150	380	404	450	356	400	442	370	450
Lead	81.6	3.2	5.8	14.9	3.9	14.9	5 U	2.5 U	2.5 U	65.6	87.1	65.9	78.9	87.1	41	55
Manganese			49.0	63.5	63.5	61.1	20.3	40	60	186	224	204	221	224	140	140
Mercury	1.7	0.91	3 U	3 U					3 U	3.0 U	3.0 U					3 U
Nickel	469	52.2	8.9	20.0 U	4.9	5.7	20 U		5 U	8.3	20.0 U	20 U	3.9	4.3		5 U
Selenium	20	5	9.2	17.5 U	9.6	13.7	17.5 U	2.5 U	2.5 U	44.7	54.1	48.1	50.4	54.1	37	34
Silver	4.1		2.8	5.0 U	R	0.81	5 U		2.5 U	2.7	5.0 U	2.1	1.2	5 U		2.5 U
Thallium			9.6 U	12.5 U	12.5 U	12.5 U	12.5 U		1 U	69.1	77.0	65.7	66	67.5		77
Vanadium			14.9	25.0 U	15.5	14.1	25 U		5 U	20.0 U	25.0 U	25 U	25 U	25 U		5 U
Zinc	120	120	82.4	118	103	118	80.9	60	50	75.1	125	77.5	125	123	10 U	40
Hardness (mg/L)			148	194	194	193	58.1			196	207	180	203	207		

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Table 3. (cont.)

Chemical	Surface Water Screening Acute	Surface Water Screening Chronic	Mean	Max	PPC_2 2003	PPC_3 2003	PPC_4 2003	PPC_5 2003	Prickly Pear Creek PPC-103 10/24/08	PPC-103 04/30/08	PPC-5 10/24/08	PPC-5 04/30/08	PPC-7 10/24/08	PPC-7 04/30/08	PPC-8 10/24/08	PPC-8 04/30/08
Dissolved metals (ug/L)																
Aluminum	750	87	75.0 U	100 U	100 U	100 U	100 U	100 U		50 U		50 U		50 U		50 U
Antimony			16.3 U	30 U	30 U	30 U	30 U	30 U		2.5 U		2.5 U		2.5 U		2.5 U
Arsenic			6.9	12.4	7.5 U	11.4	12.4	7.5 U	5	4	5	5	7	6	7	5
Barium			41.6	50 U	27.1	28.9	26.9	49.6		50 U		50 U		50 U		50 U
Beryllium			1.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U		0.5 U		0.5 U		0.5 U		0.5 U
Cadmium			0.4	0.5 U	0.1	0.23	0.17	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Chromium			2.2	5 U	5 U	0.85	5 U	5 U		0.5 U		0.5 U		0.5 U		0.5 U
Cobalt			15.0 U	25 U	25 U	25 U	25 U	25 U		5 U		5 U		5 U		5 U
Copper			4.7	12.5 U	12.5 U	3.4	12.5 U	12.5 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
Iron			124	190	81.2	177	123	58.8	190	90	190	80	160	90	160	90
Lead			3.3 U	5 U	5 U	5 U	5 U	5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Manganese			56.6	80	34.8	73.4	37.6	13.3	70	60	80	60	70	50	80	50
Mercury			3.0 U	3.0 U						3 U		3 U		3 U		3 U
Nickel			12.5 U	20.0 U	20 U	20 U	20 U	20 U		5 U		5 U		5 U		5 U
Selenium			5.2	17.5 U	17.5 U	9.3	8.4	7.1	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Silver			1.8	2.5 U		0.69	0.69	1.3		2.5 U		2.5 U		2.5 U		2.5 U
Thallium			6.8 U	12.5 U	12.5 U	12.5 U	12.5 U	12.5 U		1 U		1 U		1 U		1 U
Vanadium			4.2	5 U	2.9	3.6	2.9	3.9		5 U		5 U		5 U		5 U
Zinc			68.4	137	137	130	71.3	113	70	30	60	30	60	30	60	30
Hardness			123	141	114	118	118	141								
Total metals (ug/L)																
Aluminum			75.0 U	100 U	100 U	100 U	100 U	100 U		50 U		50 U		50 U		50 U
Antimony			16.3 U	30 U	30 U	30 U	30 U	30 U		2.5 U		2.5 U		2.5 U		2.5 U
Arsenic	340	150	7.6	11.5	7.5 U	11.5	10.1	7.5 U	6	6	6	6	8	7	8	7
Barium			41.8	50 U	29.3	27.6	27.9	49.5		50 U		50 U		50 U		50 U
Beryllium			1.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U		0.5 U		0.5 U		0.5 U		0.5 U
Cadmium	2.1	0.27	0.41	0.5 U	0.21	0.36	0.29	0.11	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Chromium	16	11	2.8 U	5.0 U	5 U	5 U	5 U	5 U		0.5 U		0.5 U		0.5 U		0.5 U
Cobalt			15.0 U	25 U	25 U	25 U	25 U	25 U		5 U		5 U		5 U		5 U
Copper	14.0	9.3	3.5	6	5	4.7	4.4	4.3	2 U	2 U	2 U	5	2 U	2 U	2 U	6
Iron		1000	306	380	269	368	327	90	330	300	350	320	310	330	300	380
Lead	81.6	3.2	4.3	9	4.1	4.7	4.9	5 U	2.5 U	2.5 U	2.5 U	5	2.5 U	6	2.5 U	9
Manganese			71.6	90	56.2	89	67.5	15.9	80	70	90	70	80	70	80	90
Mercury	1.7	0.91	3.0 U	3 U						3 U		3 U		3 U		3 U
Nickel	469	52.2	12.5 U	20 U	20 U	20 U	20 U	20 U		5 U		5 U		5 U		5 U
Selenium	20	5	7.5 U	17.5 U	17.5 U	17.5 U	17.5 U	17.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Silver	4.1		3.8 U	5.0 U	5 U	5 U	5 U	5 U		2.5 U		2.5 U		2.5 U		2.5 U
Thallium			6.8 U	12.5 U	12.5 U	12.5 U	12.5 U	12.5 U		1 U		1 U		1 U		1 U
Vanadium			15.0 U	25 U	25 U	25 U	25 U	25 U		5 U		5 U		5 U		5 U
Zinc	120	120	63.8	94.7	65.3	86.9	68.2	94.7	70	40	70	40	70	40	70	50
Hardness (mg/L)			120	139	119	108	115	139								

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Table 3. (cont.)

	Surface Water Screening				Upper Lake/Marsh Area											
Chemical	Acute	Chronic	Mean	Max	ULM_1 2003	ULM_2 2003	ULM_3 2003	ULM_4 2003	ULM_5 2003	ULM_6 2003	ULM_7 2003	ULM_8 2003	ULM_9 2003	ULM_10 2003	ULM_11 2003	ULM_12 2003
Dissolved metals (ug/L)																
Aluminum	750	87	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U
Antimony			28.4	30.0 U	30 U	10.3	30 U	30 U	30 U	30 U	30 U	30 U	30 U	30 U	30 U	30 U
Arsenic			7.5	8.2	7.5	7.5 U	7.5 U	7.5 U	6.9	8.2	7.5 U	7.5 U	7.5 U	7.5 U	7.5 U	7.5 U
Barium			32.1	43.5	13.2	43.5	34.6	32	33	25.1	30	36.8	28.8	35.8	33	39.1
Beryllium			2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Cadmium			0.38	0.50 U	0.5 U	0.43	0.12	0.5 U	0.5 U	0.5 U	0.13	0.37	0.29	0.25	0.5 U	0.5 U
Chromium			4.1	5.0 U	0.77	2.1	5 U	5 U	5 U	5 U	5 U	1	5 U	5 U	5 U	5 U
Cobalt			23.1	25.0 U	25 U	2	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U
Copper			4.7	11.7	3.2	11.7	3.2	3.4	3.5	3.7	3.3	7.7	5.1	4.1	3.1	4.8
Iron			116	185	103	112	185	119	114	89.7	106	154	106	75.2	164	59.5
Lead			5.0	6.6	5 U	5 U	3.9	3.6	5 U	5 U	5 U	5 U	5 U	6.1	5 U	6.6
Manganese			288	1940	25.1	1940	66.1	83.2	164	15.3	51.6	899	35.1	71.1	39.3	66.1
Mercury																
Nickel			20.0 U	20.0 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U
Selenium			17.5 U	17.5 U	17.5 U	17.5 U	17.5 U	17.5 U	17.5 U	17.5 U	17.5 U	17.5 U	17.5 U	17.5 U	17.5 U	17.5 U
Silver			4.3	5.0 U	1.1	5 U	0.77	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Thallium			12.5 U	12.5 U	12.5 U	12.5 U	12.5 U	12.5 U	12.5 U	12.5 U	12.5 U	12.5 U	12.5 U	12.5 U	12.5 U	12.5 U
Vanadium			23.1	25 U	2.1	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U
Zinc			65.6	139	30 U	123	30.8	45.6	139	45.9	37.6	119	73.1	57.3	56.4	30 U
Hardness			124	163	139	127	119	116	117	117	118	163	116	121	117	119
Total metals (ug/L)																
Aluminum			312	1620	132	828	100 U	100 U	1620	168	100 U	100 U	100 U	100 U	100 U	294
Antimony			30.0 U	30 U	30 U	30 U	30 U	30 U	30 U	30 U	30 U	30 U	30 U	30 U	30 U	30 U
Arsenic	340	150	11.7	31.5	7.5 U	21.4	7.5 U	9.1	14.4	10.3	7.5 U	31.5	7.5 U	7.7	7.5 U	8.4
Barium			37.6	63.5	14.6	63.5	32.2	32	45.9	27.2	26.8	58.9	35.4	34.2	35	45.5
Beryllium			2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Cadmium	2.1	0.27	1.5	5.6	0.21	2.1	0.44	0.11	2.9	0.25	0.18	3.1	1.4	0.85	1.1	5.6
Chromium	16	11	2.6	5.0 U	5 U	2.9	0.67	5 U	1.9	4.1	0.96	2.4	1.1	5 U	0.69	0.89
Cobalt			21.2	25.0 U	25 U	2.7	25 U	25 U	1.1	25 U	25 U	25 U	25 U	25 U	25 U	25 U
Copper	14.0	9.3	12.1	27.7	4	23.4	4.1	4	27.7	7.9	3.8	21.5	13.4	5.4	8.3	22.1
Iron		1000	1515	8370	120	4560	265	293	2040	215	230	8370	1000	283	201	603
Lead	81.6	3.2	44.2	156	6.9	57.6	16.5	5 U	115	19.9	5 U	68.4	20.6	31.6	28.2	156
Manganese			425	2180	47.6	2180	70.8	85.2	241	40.7	49.5	1740	382	90.1	79.2	97.9
Mercury	1.7	0.91														
Nickel	469	52.2	20.0 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U
Selenium	20	5	17.5 U	17.5 U	17.5 U	17.5 U	17.5 U	17.5 U	17.5 U	17.5 U	17.5 U	17.5 U	17.5 U	17.5 U	17.5 U	17.5 U
Silver	4.1		3.3	5.0 U	5 U	5 U	0.86	5 U	R	0.81	5 U	0.8	5 U	5 U	R	0.94
Thallium			12.5 U	12.5 U	12.5 U	12.5 U	12.5 U	12.5 U	12.5 U	12.5 U	12.5 U	12.5 U	12.5 U	12.5 U	12.5 U	12.5 U
Vanadium			18.0	25 U	2.7	5.6	25 U	25 U	3.9	25 U	25 U	3.2	25 U	25 U	25 U	25 U
Zinc	120	120	73.9	253	27.4	253	30 U	30 U	140	30 U	30 U	127	59.3	30 U	31.9	97.9
Hardness (mg/L)			119	157	133	127	107	114	122	115	107	157	111	111	112	110

Table 3. (cont.)

Chemical	Surface Water Screening Acute	Surface Water Screening Chronic	Upper Lake: Upper Lake 11/07/02	Wilson Ditch: Mean	Wilson Ditch: Max	Wilson Ditch: WD-1 06/20/02	Wilson Ditch: WD-2 06/20/02	Wilson Ditch: WD-2 06/04/01
Dissolved metals (ug/L)								
Aluminum	750	87						
Antimony								
Arsenic			5.0	7.3	10.0	10.0	7.0	5.0
Barium								
Beryllium								
Cadmium			4.0	1.3	2.0	2.0	1.0	1.0
Chromium								
Cobalt								
Copper			4.0	5.3	7.0	7.0	5.0	4.0
Iron			20.0	83.3	90.0	80.0	90.0	80.0
Lead			7.0	11.7	20.0	20.0	10.0	5.0
Manganese			100	36.7	50.0	20.0	40.0	50.0
Mercury								
Nickel								
Selenium								
Silver								
Thallium								
Vanadium								
Zinc			40.0	20.0	20	20	20	20
Hardness								
Total metals (ug/L)								
Aluminum								
Antimony								
Arsenic	340	150	30.0	7.3	10.0	10.0	7.0	5.0
Barium								
Beryllium								
Cadmium	2.1	0.27	30.0	2.0	3.0	3.0	2.0	1.0
Chromium	16	11						
Cobalt								
Copper	14.0	9.3	90.0	7.0	10.0	10.0	7.0	4.0
Iron		1000	1700	267	300	200	300	300
Lead	81.6	3.2	800	32.3	60.0	60.0	30.0	7.0
Manganese			200	53.3	60.0	40.0	60.0	60.0
Mercury	1.7	0.91						
Nickel	469	52.2						
Selenium	20	5						
Silver	4.1							
Thallium								
Vanadium								
Zinc	120	120	300	56.7	100	40.0	100	30.0
Hardness (mg/L)								

Note:

Boxed values exceed the chronic screening criteria; bolded/shaded values exceed the acute screening criteria.

Surface water screening criteria are from MDEQ (2008).

Citation: MDEQ. 2008. Circular DEQ-7, Montana Numeric Water Quality Standards February 2008. *Montana Department of Environmental Quality*, Helena, MT.

Chromium was screened as CrVI.

Hardness-dependent screening criteria for cadmium, copper, lead, nickel, silver and zinc are based on a hardness of 100 mg/L.

Nondetects are reported at half the detection limit.
Units are ug/L, unless otherwise noted.

CFR - Canyon Ferry Reservoir
R - rejected
U - undetected

Table 4. Sediment data screening

Chemical (mg/kg dry wt)	Sediment Screening Criteria		Reference Mean	Reference Max	CFR_1	CFR_2	PPC_1	Lower Lake Mean	Lower Lake Max	LL_1	LL_2	LL_3
Aluminum	26000	TEL	13130	17600	13200	17600	8590	9647	13000	4440	13000	11500
Antimony			11.9 U	12.1 U	11.6 U	12.1 U	R	624	990	990	353	530
Arsenic	9.79	TEC	13.2	15.6	12.4	15.6	11.5	2473	3030	1660	2730	3030
Barium			149	175	166	175	106	208	245	173	245	205
Beryllium			1.4	1.8	1.5	1.8	0.91	1.2	1.8	0.56	1.8	1.3
Cadmium	0.99	TEC	1.9	3.5	0.97	1.2	3.5	1687	2680	1230	1150	2680
Chromium	43.4	TEC	20.9	23.6	21.2	23.6	18	18.1	22.1	10.4	22.1	21.9
Cobalt			9.2	9.9	8.4	9.3	9.9	31.8	35.1	25.6	35.1	34.6
Copper	31.6	TEC	40.5	59.7	28.1	33.6	59.7	2140	2600	1920	1900	2600
Iron	190000	TEL	18767	20700	16100	19500	20700	27667	35200	17500	35200	30300
Lead	35.8	TEC	48	104	17.2	23.5	104	11097	14400	9470	9420	14400
Manganese	630	TEL	392	720	198	258	720	1150	1370	851	1230	1370
Mercury	0.18	TEC	0.13 U	0.145 U	0.11 U	0.145 U	R	46.6	53.3	53.3	38	48.4
Nickel	22.7	TEC	15.3	18.8	16.8	18.8	10.4	31.7	36.4	24.7	36.4	34
Selenium			6.9 U	7.05 U	6.75 U	7.05 U	R	323	432	432	221	316
Silver			2.0 U	2.0 U	1.95 U	2 U	R	112	141	101	93.7	141
Thallium			5.0 U	5.05 U	4.85 U	5.05 U	R	1188	1980	1980	700	884
Vanadium			30.5	39.7	24.1	27.8	39.7	40.8	57.7	20.4	57.7	44.4
Zinc	121	TEC	212	454	81.4	102	454	5833	6930	4490	6080	6930

Table 4. (cont.)

Chemical (mg/kg dry wt)	Sediment Screening Criteria		Prickly Pear Creek Mean	Prickly Pear Creek Max	PPC_2	PPC_3	PPC_4	PPC_5	Upper Lake/Marsh Area Mean	Upper Lake/Marsh Area Max	ULM_1	ULM_2	ULM_3
Aluminum	26000	TEL	8058	10100	7750	9500	10100	4880	14362	20000	15700	14500	15700
Antimony			4.6	7.8 U	7.75 U	4.1	4.5	1.9	31	112	19.5	1.7	5.6
Arsenic	9.79	TEC	114	250	52.1	122	250	32.1	245	581	229	121	162
Barium			206	352	135	250	352	85.3	185	282	150	213	282
Beryllium			1.1	1.4	1.1	1.3	1.4	0.63	2	2.1	1.5	1.9	2.1
Cadmium	0.99	TEC	17.4	36.8	6	22.8	36.8	4.1	120	338	112	12.2	66.9
Chromium	43.4	TEC	13.9	21.2	10.3	15.9	21.2	8.2	20	27.3	19.5	20.5	22.3
Cobalt			14.0	21.2	12.3	15.5	21.2	7	16	24.1	12.2	17.5	19.2
Copper	31.6	TEC	210	480	93.9	221	480	44.1	801	2290	686	191	430
Iron	190000	TEL	23325	38100	18600	24800	38100	11800	25083	34400	23500	32600	29200
Lead	35.8	TEC	635	1090	370	878	1090	203	3489	10400	4270	594	1470
Manganese	630	TEL	3545	9030	672	3920	9030	558	960	2520	720	2520	955
Mercury	0.18	TEC	1.6	3.1	0.43	2.5	3.1	0.27	18	59.1	14.2	0.59	4.7
Nickel	22.7	TEC	11.2	16.1	9.9	12.7	16.1	6.2	17	24.8	17.9	16.2	20.1
Selenium			2.6	5.3	1.3	2.8	5.3	1.1	9	20.4	14	2.8	4.3
Silver			1.5	2.5	1.3 U	0.85	2.5	1.2 U	37	127	29.1	0.65	10.2
Thallium			3.1 U	3.3 U	3.25 U	R	R	3 U	4	5.25	1.9	R	R
Vanadium			39.5	55.2	34	44.1	55.2	24.8	47	59.4	41.9	56.2	50.4
Zinc	121	TEC	1790	3930	925	1860	3930	444	3116	6550	1810	1680	3540

Table 4. (cont.)

Chemical (mg/kg dry wt)	Sediment Screening Criteria		Upper Lake/Marsh Area ULM_4	ULM_5	ULM_6	ULM_7	ULM_8	ULM_9	ULM_10	ULM_11	ULM_12
Aluminum	26000	TEL	11900	9490	20000	9650	12200	15600	14200	17500	15900
Antimony			16.8	10.9	68.6	1.2	6.5	0.43	60	112	64.9
Arsenic	9.79	TEC	116	124	326	54.6	297	146	337	581	452
Barium			143	111	228	120	149	214	179	201	228
Beryllium			1.2	1	1.9	1	1.3	1.7	1.6	2	2
Cadmium	0.99	TEC	42.5	46.6	199	15	38.3	17.7	238	338	316
Chromium	43.4	TEC	15.6	13.1	26.7	12.4	15.8	20.9	20.1	27.3	24.7
Cobalt			11.5	9.1	18.8	8.6	13.6	17.4	18	24.1	21.5
Copper	31.6	TEC	404	332	1270	158	391	180	1310	2290	1970
Iron	190000	TEL	18400	16000	34400	16300	19300	26200	25600	30200	29300
Lead	35.8	TEC	1170	1610	5360	486	1850	529	5140	10400	8990
Manganese	630	TEL	576	484	747	472	890	755	911	1300	1190
Mercury	0.18	TEC	5.9	14.5	27.3	1.2	10.1	2.1	28.3	50.6	59.1
Nickel	22.7	TEC	12.1	10.1	22.5	9.3	13.4	17.9	19.6	24.8	23
Selenium			4.5	3.8	14	3.2	5.2	2.9	11.5	19.9	20.4
Silver			14	11.9	59.3	2.7	14.2	1.3 *U*	64.1	127	107
Thallium			5.25	4.15 *U*	4.8	4.25 *U*	3.3 *U*	3.2 *U*	*R*	*R*	*R*
Vanadium			34	34.3	58.9	27.1	46.2	57.5	43.6	59.4	52.4
Zinc	121	TEC	2100	1680	4200	1360	2120	1670	4260	6550	6420

Note:

Boxed values exceed screening criteria.

Sediment screening criteria:

TEC - MacDonald et al. (2000)

Citation: MacDonald, D.D., C.G. Ingersoll, and T.A. Berger. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Arch. Environ. Contam. Toxicol. 39(1)20-31.

TEL - Ingersoll et al. (1996)

Citation: Ingersoll, C.G., P.S. Haverland, E.L. Brunson, T.J. Canfield, F.J. Dwyer, C.E. Henke, N.E. Kemble, D.R. Mount, and R.G. Fox. 1996. Calculation and evaluation of sediment effect concentrations for the amphipod *Hyalella azteca* and the midge *Chironomus riparius*. J. Great Lakes Res. 22(3)602-623.

Sediment data were collected in 2003.

Nondetects are reported at half the detection limit.

Units are mg/kg dry weight.

June 26, 2009

Table 5. Surface-soil data screening

Chemical	Surface Soil Screening Criteria		Mean	Max	Lower ore storage area LOS-SS03-1 3/13/2001 0-4 (in)	LOS-SS08-1 3/13/2001 0-4 (in)	LOS-SS13-1 3/13/2001 0-4 (in)	SS-8 – 0-1 (in)
Total metals (mg/kg dry wt)								
Arsenic	10	Efroymson - Plant	1493	3800		312	367	3800
Cadmium	0.36	Eco-SSL Mammalian	267	1013	30	2.5 U	24	1013
Copper	28	Eco-SSL Avian	5073	18600	146	1015	532	18600
Lead	11	Eco-SSL Avian	5775	21400	781	249	669	21400
Zinc	46	Eco-SSL Avian	3854	14250	463	244	457	14250

Chemical	Surface Soil Screening Criteria		Mean	Max	SS-21 – 0-1 (in)	SS-28 – 0-1 (in)	SS-29 – 0-1 (in)	SS-30 – 0-1 (in)	Misc_ unpaved areas SS-31 – 0-1 (in)	UPS-SS01-1 3/20/2001 0-4 (in)	UPS-SS02-1 3/16/2001 0-4 (in)	UPS-SS03-1 3/16/2001 0-4 (in)	UPS-SS04-1 3/16/2001 0-4 (in)	UPS-SS05-1 3/16/2001 0-4 (in)
Total metals (mg/kg dry wt)														
Arsenic	10	Efroymson - Plant	2782	17075	17075	8625	9525	1633	2625	33	2297	518	986	203
Cadmium	0.36	Eco-SSL Mammalian	839	3069	1693	2525	2575	373	813	3069	433	64	603	320
Copper	28	Eco-SSL Avian	6612	35350	35350	23600	23700	5600	6900	94	6011	1100	3643	787
Lead	11	Eco-SSL Avian	10477	39046	22575	1535	20300	12725	14600	8813	573	578	39046	8187
Zinc	46	Eco-SSL Avian	14746	84650	14875	23925	48550	7925	84650	4628	481	181	11096	2637

Chemical	Surface Soil Screening Criteria		Mean	Max	SS-15 – 0-1 (in)	SS-16 – 0-1 (in)	SS-23 – 0-1 (in)	UOP-SS01-1 3/29/2001 0-4 (in)	Plant perimeter sample UOP-SS02-1 3/29/2001 0-4 (in)	UOP-SS03-1 3/29/2001 0-4 (in)	UOP-SS04-1 3/29/2001 0-4 (in)	UOP-SS05-1 3/29/2001 0-4 (in)	UOP-SS06-1 3/8/2001 0-4 (in)	UOP-SS07-1 3/8/2001 0-4 (in)
Total metals (mg/kg dry wt)														
Arsenic	10	Efroymson - Plant	137	540	385	121	121	0.05 U	324	91	25	19	60	238
Cadmium	0.36	Eco-SSL Mammalian	80.4	532	172	92	212	137	227	39	69	38	2.5 U	2.5 U
Copper	28	Eco-SSL Avian	1419	18375	9750	16375	320	0.05 U	270	268	96	89	150	501
Lead	11	Eco-SSL Avian	2261	11600	3250	1368	11600	2991	7958	1534	2619	1380	277	82
Zinc	46	Eco-SSL Avian	1702	12492	3975	1868	1093	1734	12492	730	1266	657	155	85

Chemical	Surface Soil Screening Criteria		Mean	Max	RC-SA01A-1 4/23/2001 0-4 (in)	RC-SA01B-1 4/23/2001 0-4 (in)	RC-SA01C-1 4/20/2001 0-4 (in)	RC-SA01D-1 4/20/2001 0-4 (in)	Railcar staging area RC-SA01E-1 4/20/2001 0-4 (in)	RC-SA02A-1 4/24/2001 0-4 (in)	RC-SA02B-1 4/24/2001 0-4 (in)	RC-SA02C-1 4/24/2001 0-4 (in)	RC-SA02D-1 4/24/2001 0-4 (in)	RC-SA02E-1 4/24/2001 0-4 (in)
Total metals (mg/kg dry wt)														
Arsenic	10	Efroymson - Plant	2020	6171	1173	1727	1593	656	926	902	604	533	191	1634
Cadmium	0.36	Eco-SSL Mammalian	504	1185	118	547	600	1065	354	528	700	381	173	151
Copper	28	Eco-SSL Avian	6497	35750	2757	7162	4384	2126	2767	1832	4382	2785	35750	4305
Lead	11	Eco-SSL Avian	29380	62282	8064	30611	16890	30659	30206	14681	19234	15507	8989	8264
Zinc	46	Eco-SSL Avian	21395	71979	3404	18686	21098	11986	15772	8704	13173	13353	7970	11321

Chemical	Surface Soil Screening Criteria		Mean	Max	SS-1 – 0-1 (in)	SS-2 – 0-1 (in)	SS-24 – 0-1 (in)	SS-3 – 0-1 (in)	Tito Park SS-4 – 0-1 (in)	UOS-SS01-1 4/17/2001 0-4 (in)	UOS-SS02-1 4/17/2001 0-4 (in)	UOS-SS03-1 4/27/2001 0-4 (in)	UOS-SS05-1 4/17/2001 0-4 (in)	UOS-SS07-1 4/17/2001 0-4 (in)
Total metals (mg/kg dry wt)														
Arsenic	10	Efroymson - Plant	1829	8091	6075	3475	2115	1078	5650	8091	39 J2	1636 J2	1868	3037
Cadmium	0.36	Eco-SSL Mammalian	1949	14725	6000	1813	613	413	14725	1607	10646	9319	40	654
Copper	28	Eco-SSL Avian	3819	23599	14575	3225	4275	1090	12175	23599	88	6354	3515	4089
Lead	11	Eco-SSL Avian	15084	71196	19350	24975	16575	10875	23625	5186	28537	71196	376	20323
Zinc	46	Eco-SSL Avian	8888	44050	23625	10050	7325	3075	44050	2768	19494	34579	137	5105

Table 5. (cont.)

Chemical		Surface Soil Screening Criteria
Total metals (mg/kg dry wt)		
Arsenic	10	Effroymson - Plant
Cadmium	0.36	Eco-SSL Mammalian
Copper	28	Eco-SSL Avian
Lead	11	Eco-SSL Avian
Zinc	46	Eco-SSL Avian

Misc_ unpaved areas

Chemical		Surface Soil Screening Criteria	UPS-SS07-1 3/16/2001 0-4 (in)	UPS-SS08-1 3/15/2001 0-4 (in)	UPS-SS09-1 3/20/2001 0-4 (in)	UPS-SS10-1 3/20/2001 0-4 (in)	UPS-SS11-1 3/16/2001 0-4 (in)	UPS-SS12-1 3/16/2001 0-4 (in)	UPS-SS13-1 3/20/2001 0-4 (in)	UPS-SS14-1 3/20/2001 0-4 (in)
Total metals (mg/kg dry wt)										
Arsenic	10	Effroymson - Plant	0.11	60	334	1191	1748	5955	21	18
Cadmium	0.36	Eco-SSL Mammalian	945	80	31	105	116	192	843	1160
Copper	28	Eco-SSL Avian	0.05 *U*	1296	1100	4101	8221	4039	40	23
Lead	11	Eco-SSL Avian	10425	2624	917	2439	3255	14172	14989	21303
Zinc	46	Eco-SSL Avian	6421	1347	1611	5345	3560	12858	8045	41988

Plant perimeter sample

Chemical		Surface Soil Screening Criteria	UOP-SS08-1 3/8/2001 0-4 (in)	UOP-SS09-1 3/8/2001 0-4 (in)	UOP-SS10-1 3/8/2001 0-4 (in)	UOP-SS11-1 3/8/2001 0-4 (in)	UOP-SS12-1 3/22/2001 0-4 (in)	UOP-SS13-1 3/22/2001 0-4 (in)	UOP-SS14-1 3/22/2001 0-4 (in)	UOP-SS15-1 3/22/2001 0-4 (in)	UOP-SS16-1 3/22/2001 0-4 (in)	UOP-SS17-1 3/22/2001 0-4 (in)	UOP-SS18-1 3/22/2001 0-4 (in)
Total metals (mg/kg dry wt)													
Arsenic	10	Effroymson - Plant	540	236	0.47	124	81	34	25	48	29	145	101
Cadmium	0.36	Eco-SSL Mammalian	32	116	532	99	71	28	16	10	2.5 *U*	2.5 *U*	2.5 *U*
Copper	28	Eco-SSL Avian	1702	133	0.05 *U*	3903	467	314	186	258	235	415	200
Lead	11	Eco-SSL Avian	632	2199	7634	2071	2371	884	757	472	216	552	307
Zinc	46	Eco-SSL Avian	314	1001	5319	674	2843	576	738	1594	135	1377	189

Railcar staging area

Chemical		Surface Soil Screening Criteria	RC-SA02F-1 4/24/2001 0-4 (in)	RC-SA04-1 4/24/2001 0-4 (in)	RC-SA05A-1 4/24/2001 0-4 (in)	RC-SA05B-1 4/23/2001 0-4 (in)	RC-SA05C-1 4/23/2001 0-4 (in)	RC-SA05D-1 4/23/2001 0-4 (in)	RC-SA05E-1 4/23/2001 0-4 (in)	RC-SA05F-1 4/23/2001 0-4 (in)	RC-SA06-1 4/24/2001 0-4 (in)	RC-SA07-1 4/25/2001 0-4 (in)	RC-SA08A-1 4/25/2001 0-4 (in)
Total metals (mg/kg dry wt)													
Arsenic	10	Effroymson - Plant	3255	2464	3511	3407	2358	2067	2880	2593	3889	3234	1411
Cadmium	0.36	Eco-SSL Mammalian	40	665	488	672	1185	1048	767	751	527	683	809
Copper	28	Eco-SSL Avian	10724	3196	6447	9688	6009	6317	12208	5903	7271	10354	2755
Lead	*11*	Eco-SSL Avian	*1913*	*32348*	*61147*	*54667*	*62282*	*61424*	*39682*	*32478*	*46977*	*47871*	*58640*
Zinc	46	Eco-SSL Avian	3611	21874	41638	34496	52549	33013	26441	19404	71979	34445	37734

Tito Park

Chemical		Surface Soil Screening Criteria	UOS-SS08-1 4/17/2001 0-4 (in)	UOS-SS10-1 10/3/2001 0-4 (in)	UOS-SS11-1 10/3/2001 0-4 (in)	UOS-SS12-1 10/3/2001 0-4 (in)	UOS-SS13-1 10/3/2001 0-4 (in)	UOS-SS14-1 10/3/2001 0-4 (in)	UOS-SS15-1 10/3/2001 0-4 (in)	UOS-SS16-1 10/3/2001 0-4 (in)	UOS-SS17-1 10/3/2001 0-4 (in)	UOS-SS18-1 10/3/2001 0-4 (in)	UOS-SS19-1 10/3/2001 0-4 (in)
Total metals (mg/kg dry wt)													
Arsenic	10	Effroymson - Plant	3318	2632	0.006	3938	1269	533	961	972	0.058	869	136
Cadmium	0.36	Eco-SSL Mammalian	791	844	555	714	1046	675	354	204	276	582	120
Copper	28	Eco-SSL Avian	4818	5111	0.041	8067	3252	866	1673	1939	0.007	2235	52
Lead	11	Eco-SSL Avian	20210	19221	21913	29987	21982	15954	10625	4556	10990	9676	16256
Zinc	46	Eco-SSL Avian	8599	9197	7648	12553	7967	7973	7135	3166	4852	6578	6075

Table 5. (cont.)

Chemical		Surface Soil Screening Criteria
Total metals (mg/kg dry wt)		
Arsenic	10	Effroymson - Plant
Cadmium	0.36	Eco-SSL Mammalian
Copper	28	Eco-SSL Avian
Lead	11	Eco-SSL Avian
Zinc	46	Eco-SSL Avian

Chemical		Surface Soil Screening Criteria
Total metals (mg/kg dry wt)		
Arsenic	10	Effroymson - Plant
Cadmium	0.36	Eco-SSL Mammalian
Copper	28	Eco-SSL Avian
Lead	11	Eco-SSL Avian
Zinc	46	Eco-SSL Avian

			Plant perimeter sample		
			UOP-SS19-1	UOP-SS20-1	UOP-SS21-1
		Surface Soil Screening	3/21/2001	3/21/2001	3/21/2001
Chemical		Criteria	0-4 (in)	0-4 (in)	0-4 (in)
Total metals (mg/kg dry wt)					
Arsenic	10	Effroymson - Plant	387	0.05 *U*	420
Cadmium	0.36	Eco-SSL Mammalian	80	28	79
Copper	28	Eco-SSL Avian	500	0.05 *U*	703
Lead	11	Eco-SSL Avian	2706	1094	3811
Zinc	46	Eco-SSL Avian	2585	946	1816

			Railcar staging area			
			RC-SA08B-1	RC-SA08C-1	RC-SA08D-1	RC-SA08E-1
		Surface Soil Screening	4/25/2001	4/25/2001	4/25/2001	4/25/2001
Chemical		Criteria	0-4 (in)	0-4 (in)	0-4 (in)	0-4 (in)
Total metals (mg/kg dry wt)						
Arsenic	10	Effroymson - Plant	1049	763	5516	6171
Cadmium	0.36	*Eco-SSL Mammalian*	849	195	264	238
Copper	28	Eco-SSL Avian	3158	2114	7755	13210
Lead	11	Eco-SSL Avian	55755	22576	18475	13901
Zinc	46	Eco-SSL Avian	39989	14419	11613	8891

			Tito Park			
			UOS-SS20-1	UOS-SS4-1	UOS-SS8-1	UOS-SS9-1
		Surface Soil Screening	10/3/2001	4/26/2001	4/26/2001	4/26/2001
Chemical		Criteria	0-4 (in)	0-4 (in)	0-4 (in)	0-4 (in)
Total metals (mg/kg dry wt)						
Arsenic	10	Effroymson - Plant	391	735	437	115
Cadmium	0.36	Eco-SSL Mammalian	72	39	412	108
Copper	28	Eco-SSL Avian	641	639	690	87
Lead	11	Eco-SSL Avian	1202	443	2628	596
Zinc	46	Eco-SSL Avian	1240	367	1264	5066

Table 5. (cont.)

Notes:

Boxed values exceed screening criteria.

Surface soil was screened using the minimum screening criteria from U.S EPA (2009) and Efroymson (1997):

Eco-SSL Avian
Eco-SSL Mammalian
Citation: U.S. EPA. 2009. Ecological Soil Screening Level (Eco-SSL) website, http://www.epa.gov/ecotox/ecossl/ last updated on May 21, 2008. Accessed June 18, 2009. U.S. Environmental Protection Agency, Washington, D.C.

Efroymson - Plant
Citation: Efroymson, R.A., M.E. Will, G.W. Suter II, and A.C. Wooten. 1997. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision. Oak Ridge National Laboratory, Oak Ridge, TN. 128 pp. ES/ER/TM-85/R3.

Nondetects are reported at half the detection limit.
Units are mg/kg dry weight.

J2 - Estimated

Table 6. Summary of remediation-related activities completed at the Asarco East Helena facility

Date	SURFACE SOILS AND ORE STORAGE AREA	LOWER LAKE	FORMER THORNOCK LAKE	FORMER SPEISS SETTLING POND & GRANULATING PIT	ACID PLANT WATER	ACID PLANT SEDIMENT DRYING AREA	PLANT WATER CIRCUIT	SURFACE WATER
1977 - 1988			October 1986 - Thornock Lake replaced with 93,000 gal. steel tank. 1986 through 1987 - Soil excavated from Thornock Lake Area.	Fall 1988 - Speiss Pond lined with HPDE.		1977 through July 1991 - Acid plant sludge (sediments) sent to sediment drying pad for dewatering.	1988 - Plant water-balance study initiated as part of RI/FS.	
1989	Construction of new ore storage building. Shallow soils removed and stored in lower ore storage area, deeper soils consolidated in berm along southeast corner of the storage yard.	October - December 1989 - Bench-scale testing for the treatment of Lower Lake water.		Constructed new Speiss settling tank with secondary leak detection to replace Speiss Pond. Soils excavated to 20 ft under portion of former Speiss Pond. 2,500 CY of excavated soil stockpiled in the outside ore storage yard area for future smelting.		1988-89 - Soil samples collected from backhoe pits in area between Upper and Lower Lakes and east of acid plant sediment drying pad.	1989 - Plant water-balance study indicates extraneous water gains.	
1990	MAY 1990 - New ore storage building began operation.	1990 - Regular direct discharge of plant water to Lower Lake discontinued following installation of storage tanks. Occasional discharge of excess water from tanks to Lower Lake. January - September 1990 - Pilot scale testing for in-situ treatment of Lower Lake water.				DECEMBER 1990 - Monitoring well DH-29 found buried in acid plant sludge during post-RI monitoring.	1990 - Installed two, 1-mgal plant water storage tanks.	

Table 6. (cont.)

Date	SURFACE SOILS AND *ORE STORAGE AREA*	LOWER LAKE	FORMER THORNOCK *LAKE*	FORMER SPEISS SETTLING POND & GRANULATING PIT	ACID PLANT WATER	ACID PLANT SEDIMENT *DRYING AREA*	PLANT WATER CIRCUIT	SURFACE WATER
1991		October 1991 - Bottom sediment core samples collected from Lower Lake.	November 1991 - Additional excavation of soils from former Thornock Lake area. 407 CY of excavated soils smelted.	April 1991- Water granulation of Speiss replaced with air granulation.	April 1991 - Eliminated wooden trough fluid transport system and settling dumpsters, reducing water losses. Settling pond remained in service.	July 1991 - Acid plant sediments removed from former sediment drying pad between Upper and Lower Lakes. Dried acid plant sludge placed near acid plant water treatment facility.	April 1991 - Additional process water gains occur as a result of remediation activities at acid plant facility. December 1991 - Reduction in plant circuit gains. Repaired and replaced pipes, reduced bleeder valves. New plant water balance study indicates net gain of about 40 GPM.	
1992	November 1992 - Monitoring well DH-8 in lower ore storage yard is damaged.	April 1992 - Additional bottom sediment core samples collected from Lower Lake.		October 1992 - Completed Speiss pond remediation consisting of demolition of remaining pond and adjacent soil removal. Exposed leaking plant water drain line south of Speiss pit during remediation. Drain line temporarily repaired.	November 1992 - Completed acid plant water reclamation facility goes on-line.	November 1992 - Practice of placing acid plants sediments on outside drying pad discontinued following completion of acid plant water reclamation facility.		
1993		April 1993 - Construction of HDS plant started. May 1993 - Acid plant reclaim water is discharged to Lower Lake during interim period prior to HDS plant start-up. August 1993 - Lab testing of Lower Lake sediment dewatering is completed. November 1993 - Large-scale dredging and dewatering pilot testing of Lower Lake sediments.		April 1993 - Additional temporary repairs to drain line south of Speiss pit. May 1993 - Placement of new drain lines in Speiss pit Area. Plant water drain line south of Speiss pit permanently repaired. August 1993 - Concrete cap poured over backfill material in former Speiss pond area.	February 1993 - Acid plant settling pond is demolished. May 1993 - Soil excavation and backfill of acid settling pond us completed.	September 1993 - Former acid plant drying pad is sealed.	May 1993 - New plant water drain lines and wet well installed in Speiss pit area.	

Table 6. (cont.)

Date	SURFACE SOILS AND ORE STORAGE AREA	LOWER LAKE	FORMER THORNOCK LAKE	FORMER SPEISS SETTLING POND & GRANULATING PIT	ACID PLANT WATER	ACID PLANT SEDIMENT DRYING AREA	PLANT WATER CIRCUIT	SURFACE WATER
1994		January 1994 - HDS water treatment comes on-line. All untreated plant water discharges to Lower Lake cease. May 1994 - Dredging of Lower Lake sediments begins. November 1994 - Winter shutdown of Lower Lake dredging.				1994 - A belt filter press is set up in former acid plant sediment drying area to dewater dredged Lower Lake sediments. Dewatered sediments are hauled to lower ore storage yard for temporary storage.		
1995		April 1995 - Spring startup of Lower Lake dredging. November 1995 - Winter shutdown of Lower Lake dredging.		June-July 1995 - Construction of new Dross Reverberatory Furnace building and Speiss Granulating pit. July 1995 - Old Speiss pit removed. Soil excavated beneath pit to 17 ft depth (235 CY removed). August 1995 - Concrete cap placed over backfilled Speiss pit-area.		1995 - Belt filter used to dewater dredged Lower Lake sediments in sediment drying area. Dewatered sediments stockpiled in lower ore storage yard.		
1996		June 1996 - Spring startup of Lower Lake dredging. August 1996 - Lower Lake dredging completed. October 1996 - Start of *HDS Treatment Plant* optimization improvements. November 1996 - MPDES permit issued for HDS plant discharge.				1996 - Dewatering of dredged Lower Lake sediments is completed. Demobilization of belt filter presses and related equipment from area. August - September 1996 - Shallow bore holes drilled and soil samples collected from beneath former sediment drying pad.		1996 - Switch to use of Upper Lake Water rather than Lower Lake water for dust control.

Table 6. (cont.)

Date	SURFACE SOILS AND ORE STORAGE AREA	LOWER LAKE	FORMER THORNOCK LAKE	FORMER SPEISS SETTLING POND & GRANULATING PIT	ACID PLANT WATER	ACID PLANT SEDIMENT DRYING AREA	PLANT WATER CIRCUIT	SURFACE WATER
1997	October 1997 - Geomembrane cover is installed over stockpiled Lower Lake sediments as a temporary cover.	March 1997 - HDS treatment plant optimization improvements completed. November 1997 - Modified MPDES permit issued for HDS plant discharge, with final limits established for Pb, Hg, T1, Sb (limits become effective in 1998 and 1999).			February 1997 - 1200 gallons sulfuric acid spilled at acid plant decolorization building. February 15, 1997 - 20 gallons of scrubber blowdown water discharged from open packed scrubber pray tower. 10 gallons released to the environment. September 1997 - Rebricked scrubber sump at acid plant and installed secondary containment around scrubber complex. November 30, 1997 - Sulfur trioxide emission release.		December 1997 - Water-proofing begins on plant water pump house to reduce groundwater inflow.	May-June 1997 - Wilson Ditch is rerouted around plant site. June - December 1997 - Plant stormwater system improvements are constructed.
1998		March 1998 - Zeolite pilot test for thallium removal in HDS effluent completed. Unsuccessful removal. April 1998 - ASARCO contacts MDEQ concerning final MPDES limits. MDEQ grants ASARCO 6 months of feasibility testing for technology to remove T1 and Sb.			January 5, 1998 - 450 gallons of acid plant scrubber/blowdown water. Released in acid plant scrubber area. January 27, 1998 - 500 gallons of sulfuric acid released immediately west of acid plant decolorization building. January 28, 1998 - 300 gallons of sulfuric acid released to soil adjacent to sump. April 21, 1998 - 400 gallons of sulfuric acid released from broken acid plant transfer line. April 21, 1998 - 400 gallons of sulfuric acid released from acid plant transfer line. June 2, 1998 - 100-200 gallons of acid plant scrubber water released from acid plant water treatment area.		January 1998 - Water-proofing is completed on plant water pumphouse. February 1998 - Loss in plant underground circuit. Pressurized underground piping replaced with above-ground system. November 1998 - 10 gallons of plant water released from broken pipe by powerhouse.	

Table 6. (cont.)

Date	SURFACE SOILS AND ORE STORAGE AREA	LOWER LAKE	FORMER THORNOCK LAKE	FORMER SPEISS SETTLING POND & GRANULATING PIT	ACID PLANT WATER	ACID PLANT SEDIMENT DRYING AREA	PLANT WATER CIRCUIT	SURFACE WATER
1998 (continued)					August 13, 1998 - 1500 gallons of acid plant cooling water released from underground pipe leak. September 23, 1998 - 10 gallons of sulfuric acid released from acid plant decolorization building. October 3, 1998 - 30-50 gallons of sulfuric acid released from acid plant pump tank building. October 8, 1998 - 30 gallons of sulfuric acid released from acid plant tail gas stack base. October 12 - 13, 1998 - 5.1 and 10.4 pounds of arsenic released to Lower Lake from the HDS water treatment plant. November 20, 1998 - 200-300 gallons of sodium bisulfite solution discharged from the acid plant boiler room. December 13, 1998 - 50-75 gallons of sulfuric acid discharged to acid decolorization containment area. No acid was released to the environment. December 29, 1998 - 1000 gallons of sulfuric acid released from broken acid transfer line.			

Table 6. (cont.)

June 26, 2009

Date	SURFACE SOILS AND ORE STORAGE AREA	LOWER LAKE	FORMER THORNOCK LAKE	FORMER SPEISS SETTLING POND & GRANULATING PIT	ACID PLANT WATER	ACID PLANT SEDIMENT DRYING AREA	PLANT WATER CIRCUIT	SURFACE WATER
2001						Removed soil stockpile and debris piles and place in CAMU. Cover area between Upper and Lower Lake with 12" clay soil cover, grade and compact.		
2006						Construct slurry wall and temporary cap around acid plant subsurface soils		
2007				Construct slurry wall and temporary cap around speiss-dross plant subsurface soils				

June 26, 2009

Table 7. Montana Species of Concern for Lewis and Clark County

Group	Scientific Name	Common Name	Global Rank	State Rank	USFWS	USFS	BLM
Mammals	*Canis lupus*	Gray Wolf	G4	S3	DM	SENSITIVE	SPECIAL STATUS
Mammals	*Corynorhinus townsendii*	Townsend's Big-eared Bat	G4	S2		SENSITIVE	SENSITIVE
Mammals	*Cynomys ludovicianus*	Black-tailed Prairie Dog	G4	S3		SENSITIVE	SENSITIVE
Mammals	*Euderma maculatum*	Spotted Bat	G4	S2		SENSITIVE	SENSITIVE
Mammals	*Gulo gulo*	Wolverine	G4	S3		SENSITIVE	SENSITIVE
Mammals	*Lynx canadensis*	Canada Lynx	G5	S3	LT	THREATENED	SPECIAL STATUS
Mammals	*Martes pennanti*	Fisher	G5	S3		SENSITIVE	SENSITIVE
Mammals	*Myotis thysanodes*	Fringed Myotis	G4G5	S3			SENSITIVE
Mammals	*Synaptomys borealis*	Northern Bog Lemming	G4	S2		SENSITIVE	
Mammals	*Ursus arctos*	Grizzly Bear	G4	S2S3	LT,XN,DM	THREATENED	SPECIAL STATUS
Birds	*Accipiter gentilis*	Northern Goshawk	G5	S3			SENSITIVE
Birds	*Ammodramus bairdii*	Baird's Sparrow	G4	S3B			SENSITIVE
Birds	*Ammodramus savannarum*	Grasshopper Sparrow	G5	S3B			
Birds	*Anthus spragueii*	Sprague's Pipit	G4	S3B			SENSITIVE
Birds	*Buteo regalis*	Ferruginous Hawk	G4	S3B			SENSITIVE
Birds	*Calcarius mccownii*	McCown's Longspur	G4	S3B			SENSITIVE
Birds	*Calcarius ornatus*	Chestnut-collared Longspur	G5	S2B			SENSITIVE
Birds	*Cygnus buccinator*	Trumpeter Swan	G4	S3		SENSITIVE	SENSITIVE
Birds	*Dolichonyx oryzivorus*	Bobolink	G5	S3B			
Birds	*Falco peregrinus*	Peregrine Falcon	G4	S3B	DM	SENSITIVE	SENSITIVE
Birds	*Gavia immer*	Common Loon	G5	S3B		SENSITIVE	SENSITIVE
Birds	*Haliaeetus leucocephalus*	Bald Eagle	G5	S3	DM	THREATENED	SPECIAL STATUS
Birds	*Histrionicus histrionicus*	Harlequin Duck	G4	S2B		SENSITIVE	SENSITIVE
Birds	*Lagopus leucura*	White-tailed Ptarmigan	G5	S3			
Birds	*Leucosticte tephrocotis*	Gray-crowned Rosy-Finch	G5	S2B,S5N			
Birds	*Melanerpes lewis*	Lewis's Woodpecker	G4	S2B			
Birds	*Numenius americanus*	Long-billed Curlew	G5	S3B			SENSITIVE
Birds	*Oreoscoptes montanus*	Sage Thrasher	G5	S3B			SENSITIVE
Birds	*Otus flammeolus*	Flammulated Owl	G4	S3B		SENSITIVE	SENSITIVE
Birds	*Picoides arcticus*	Black-backed Woodpecker	G5	S3		SENSITIVE	SENSITIVE
Birds	*Spizella breweri*	Brewer's Sparrow	G5	S3B			SENSITIVE
Amphibians	*Bufo boreas*	Western Toad	G4	S2		SENSITIVE	SENSITIVE
Amphibians	*Bufo cognatus*	Great Plains Toad	G5	S2		SENSITIVE	SENSITIVE
Amphibians	*Spea bombifrons*	Plains Spadefoot	G5	S3		SENSITIVE	SENSITIVE
Fish	*Oncorhynchus clarkii lewisi*	Westslope Cutthroat Trout	G4T3	S2		SENSITIVE	SENSITIVE
Fish	*Salvelinus confluentus*	Bull Trout	G3	S2	LT	THREATENED	SPECIAL STATUS

Table 7. (cont.)

Group	Scientific Name	Common Name	Global Rank	State Rank	USFWS	USFS	BLM
Invertebrates	*Oreohelix alpina*	Alpine Mountainsnail	G1	S1			
Invertebrates	*Oreohelix elrodi*	Carinate Mountainsnail	G1	S1			
Vascular Plants	*Amerorchis rotundifolia*	Round-leaved Orchis	G5	S2S3		SENSITIVE	SENSITIVE
Vascular Plants	*Astragalus convallarius*	Lesser Rushy Milkvetch	G5	S2			SENSITIVE
Vascular Plants	*Atriplex truncata*	Wedge-leaved Saltbush	G5	S1			
Vascular Plants	*Botrychium sp. (SOC)*	Moonworts	G1G2G3	S1S3			
Vascular Plants	*Cardamine rupicola*	Cliff Toothwort	G3	S3			
Vascular Plants	*Cirsium longistylum*	Long-styled Thistle	G3	S3			SENSITIVE
Vascular Plants	*Cypripedium passerinum*	Sparrow's-egg Lady's-slipper	G4G5	S2		SENSITIVE	
Vascular Plants	*Delphinium bicolor ssp. calcicola*	Limestone Larkspur	G4G5T3	S3			
Vascular Plants	*Downingia laeta*	Great Basin Downingia	G5	S1			
Vascular Plants	*Draba densifolia*	Dense-leaf Draba	G5	S2			
Vascular Plants	*Drosera anglica*	English Sundew	G5	S2S3		SENSITIVE	
Vascular Plants	*Drosera linearis*	Linear-leaved Sundew	G4	S1		SENSITIVE	
Vascular Plants	*Eleocharis rostellata*	Beaked Spikerush	G5	S2		SENSITIVE	
Vascular Plants	*Erigeron lackschewitzii*	Lackschewitz' Fleabane	G3	S2		SENSITIVE	
Vascular Plants	*Erigeron linearis*	Linear-leaf Fleabane	G5	S1			SENSITIVE
Vascular Plants	*Phlox kelseyi var. missoulensis*	Missoula Phlox	G2	S2		SENSITIVE	
Vascular Plants	*Physaria klausii*	Divide Bladderpod	G3	S3			
Vascular Plants	*Polygonum austiniae*	Austin's Knotweed	G5T4	S2S3		SENSITIVE	
Vascular Plants	*Saussurea densa*	Dwarf Saw-wort	G4	S1S2			
Vascular Plants	*Scirpus subterminalis*	Water Bulrush	G4G5	S2		SENSITIVE	
Nonvascular Plants	*Scorpidium scorpioides*	Scorpidium moss	G4G5	S2		SENSITIVE	SENSITIVE
Nonvascular Plants	*Solorina spongiosa*	Fringed Chocolate Chip Lichen	G4G5	S1S2			
Nonvascular Plants	*Sphagnum fimbriatum*	Fringed Bogmoss	G5	S1			

Note: Source: Montana Natural Heritage Program
Species status codes are provided at http://fieldguide.mt.gov/statusCodes.aspx#usfws

Table 8. Assessment endpoints and measures of exposure and effect

		Assessment Endpoints					
		Terrestrial/ Wetland Plants	Soil Fauna	Benthic Invertebrates	Fish	Aquatic-Dependent Birds/Mammals	Upland/Terrestrial Birds
	Exposure Areas:	Onsite and adjacent uplands, Upper Lake Marsh, Prickly Pear Creek riparian zone	Onsite and adjacent uplands, Prickly Pear Creek riparian zone	Prickly Pear Creek, Lower Lake, Upper Lake, Upper Lake Marsh, Wilson Ditch	Prickly Pear Creek, Lower Lake, Upper Lake	Prickly Pear Creek, Lower Lake, Upper Lake, Upper Lake Marsh, Wilson Ditch	Onsite and adjacent uplands, Upper Lake Marsh, Prickly Pear Creek riparian zone
	Endpoint Attributes						
Measures of Exposure							
Surface-Water Concentrations	Survival	✓		✓	✓	✓	✓
Hyporheic Water Concentrations	Survival			✓	✓		
Sediment Concentrations	Survival	✓		✓	✓	✓	
Surface-Soil Concentrations	Survival	✓	✓				✓
Plant Tissue Concentrations	Bioaccumulation					✓	
Prey Item Concentrations	Bioaccumulation				✓	✓	✓
Measures of Ecosystem and Receptor Characteristics							
Sediment Characteristics (AVS/SEM, Grain Size, TOC)	Bioavailability	✓		✓			
Surface-Soil Characteristics (pH, TOC, Grain Size)	Bioavailability	✓	✓				
Surface-Water Parameters (pH, DO, Hardness)	Bioavailability			✓	✓		
Habitat Characterization and Ecological Community Observations	Ecosystem Health	✓	✓	✓	✓	✓	✓
Measures of Effect							
Body Weight/Growth	Growth	✓		✓	✓	✓	✓
Reproductive Success	Reproduction		✓	✓	✓	✓	✓
Mortality	Survival	✓	✓	✓	✓	✓	✓

Table 9. Site characterization samples for Phase I BERA field study

Exposure Area	Sample Locations	Sample Media: Surface Water	Sample Media: Sediment	Sample Media: Surface Soil	Location Map
Prickly Pear Creek	PPC-103	X	X		Figures 7 and 8
	PPC-5	X	X		
	PPC-7	X	X		
	PPC-8	X	X		
	Surface Water/Sediment - 1 more site	X	X		
	Riparian zone - 5 sites			x	
Wilson Ditch	WD-2	X	X		Figure 6
	WD-3	X	X		
	WD-4	X	X		
Lower Lake	Surface Water/Sediment - 5 sites	X	X		Figure 8
	Bank Soils - 4 sites			X	
Upper Lake	Surface Water/Sediment - 5 sites	X	X		Figure 8
	Bank Soils - 4 sites			X	
Upper Lake Marsh	9 sites	X	X		Figure 8
Plant Perimeter Soils	UOPSS-2			X	Figure 4
	UOPSS-4			X	
	UOPSS-9			X	
	UOPSS-12			X	
	UOPSS-17			X	
	UOPSS-20			X	
Tito Park (area between Lower and Upper Lakes)	UOSS-8			X	Figure 4
	UOSS-10			X	
	UOSS-14			X	
	Surface Soil - 2 more sites			X	
Lower Ore Storage Area	LOS SS-3			X	Figure 4
	LOS SS-8			X	
	LOS SS-9			X	
	LOS SS-15			X	
Rail Car Staging Area	RCSA-2			X	Figure 4
	RCSA-5			X	
	RCSA-8			X	
Misc. Unpaved Areas	UPS SS-5			X	Figure 4
	UPS SS-9			X	
	UPS SS-11			X	
	UPS SS-12			X	
Reference-Site Samples					
Prickly Pear Creek Upstream	PPC-REF1	X	X		To be determined
	PPC-REF2	X	X		
	PPC-REF3	X	X		
	PPC-REF4	X	X		
	PPC-REF5	X	X		
Lake Reference Site	Surface Water/Sediment - 5 sites	X	X		To be determined
	Bank Soils - 5 sites			X	
Marsh Reference Site	5 sites	X	X		To be determined
Local Background (upland)	5 sites			X	To be determined

Table 10. Summary of biota sample collection for Phase I field study

Type of Tissue:	Fish Fillet	Earthworms	Soil Invertebrates	Benthic Invertebrates	Forage Fish	Piscivorous Fish	Amphibians	Other aquatic prey species (snails, mussels, crayfish)	Aquatic Plants/Algae
Sample Objectives:	Estimate human exposure	Estimate shrew & robin exposure	Estimate shrew, tree swallow, & robin exposure	Estimate tree swallow & predatory fish exposure	Estimate belted kingfisher, mink, & piscivorous fish exposure	Measure fish exposure, estimate mink exposure	Estimate mink & belted kingfisher exposure	Estimate mink & belted kingfisher exposure	Estimate mallard exposure
Site Samples									
Prickly Pear Creek (and banks)	5	3	3	5	5	5	5	5	5
Lower Lake (and banks)		2	2	5	5		5	5	5
Upper Lake (and banks)	5	2	2	5	5	5	5	5	5
Area between Upper/Lower Lakes		2	2						
Upper Lake Marsh		3		5	5		5	5	5
Onsite Upland Areas		5	5						
Reference Site Samples									
Prickly Pear Creek Reference Site	5	5		5	5	5	5	5	5
Lake Reference Site	5			5	5	5	5	5	5
Marsh Reference Site		5		5	5		5	5	5
Upland Area Reference Site		5	5						
QA Samples									
Field Duplicates	1	1	1	1	1	1	1	1	1
Matrix Spike	1	1	1	1	1	1	1	1	1
Matrix Spike Duplicate	1	1	1	1	1	1	1	1	1
Total Number Samples	23	35	22	38	38	23	38	38	38
							Total Number of Biota Samples:		**293**

Note: Samples are composites of individual organisms to attain sufficient tissue mass for chemical analysis.

Table 11. Sediment and soil sample analytical parameter list

Parameter	Analytical Method(1)	Soil Sample Project-Required Detection Limit (mg/kg)	Sediment Sample Project-Required Detection Limit (mg/kg)
Aluminum (Al)	SW 3050/6010B/6020	100	100
Antimony (Sb)	SW 3050/6010B/6020	0.1	0.5
Arsenic (As)	SW 3050/6010B/6020	0.1	1
Barium (Ba)	SW 3050/6010B/6020	100	100
Beryllium (Be)	SW 3050/6010B/6020	10	10
Cadmium (Cd)	SW 3050/6010B/6020	0.1	0.5
Chromium (Cr)	SW 3050/6010B/6020	5	5
Cobalt (Co)	SW 3050/6010B/6020	1	1
Copper (Cu)	SW 3050/6010B/6020	5	5
Iron (Fe)	SW 3050/6010B/6020	100	100
Lead (Pb)	SW 3050/6010B/6020	1	1
Manganese (Mn)	SW 3050/6010B/6020	10	10
Mercury (Hg)	SW 7471/6010B/6020	0.05	0.05
Nickel (Ni)	SW 3050/6010B/6020	5	5
Selenium (Se)	SW 3050/6010B/6020	0.5	0.5
Silver (Ag)	SW 3050/6010B/6020	2	0.1
Thallium (Tl)	SW 3050/6010B/6020	0.1	1
Vanadium (V)	SW 3050/6010B/6020	1	10
Zinc (Zn)	SW 3050/6010B/6020	5	10
Methyl Mercury (MeHg)	EPA Method 1630	0.02 ng/kg	0.02 ng/kg
Acid Volatile Sulfide (AVS)	AVSSEM SOP v2.0-4 Sep 92	Sediment Only	0.7 umol/g
Simultaneously Extracted Metals (SEM)			
SEM Cadmium	AVSSEM SOP v2.0-4 Sep 92	Sediment Only	0.001 umol/g
SEM Copper	AVSSEM SOP v2.0-4 Sep 92	Sediment Only	0.03 umol/g
SEM Lead	AVSSEM SOP v2.0-4 Sep 92	Sediment Only	0.03 umol/g
SEM Nickel	AVSSEM SOP v2.0-4 Sep 92	Sediment Only	0.02 umol/g
SEM Zinc	AVSSEM SOP v2.0-4 Sep 92	Sediment Only	0.03 umol/g
Particle Size Distribution	ASTM D-422	NA	NA
Moisture Content	EPA Method 160.3	0.1%	0.1%
Total Organic Carbon (TOC)	EPA Method 9060	0.01%	0.01%
pH	SW 9045	0.1 s.u.	0.1 s.u.

(1) Laboratory analytical methods are from EPA's Test Methods for Analysis of Solid Waste (SW-846). Equivalent procedures may be used as long as detection limits are achieved

Table 12. Surface-water sample analytical parameter list

Parameter	Analytical Method[1]	Project-Required Detection Limit (mg/L)
	Field Parameters	
pH	Field SOP	None
Specific Conductance	Field SOP	None
Dissolved Oxygen	Field SOP	None
Water Temperature	Field SOP	None
Turbidity	Field SOP	None
Stream Flow	Field SOP	None
	Laboratory Parameters	
Major Ions and Physical Parameters		
pH	150.2	0.1 standard units
Calcium (Ca)	215.1/200.7	5
Magnesium (Mg)	242.1/200.7	5
Sodium (Na)	273.1/200.7	5
Potassium (K)	258.1/200.7	5
Sulfate (SO_4)	300.0	1
Chloride (Cl)	300.0	1
Total Alkalinity as $CaCO_3$	SM 2320B	5
Total Dissolved Solids	SM 2540C	10
Total Suspended Solids	SM 2540D	10
Metals (Dissolved and Total Recoverable)		
Aluminum (Al)	200.7/200.8	0.05
Antimony (Sb)	200.7/200.8	0.003
Arsenic (As)	200.8	0.0005
Barium (Ba)	200.7/200.8	0.1
Beryllium (Be)	200.7/200.8	0.001
Cadmium (Cd)	200.8/200.9	0.0001
Chromium (Cr)	200.7/200.8	0.001
Cobalt (Co)	200.7/200.8	0.0005
Copper (Cu)	200.7/200.8	0.001
Iron (Fe)	200.7/200.8	0.02
Lead (Pb)	200.8	0.0005
Manganese (Mn)	200.7/200.8	0.01
Mercury (Hg)	200.8/245.1/245.2/245.7	0.00001
Nickel (Ni)	200.7/200.8	0.01
Selenium (Se)	200.8/200.9	0.001
Silver (Ag)	200.8/200.9	0.0005
Thallium (Tl)	200.8/200.9	0.0002
Vanadium (V)	200.7/200.8	0.1
Zinc (Zn)	200.7/200.8/200.9	0.01
Methyl Mercury (MeHg)	EPA Method 1630	0.02 ng/L

(1) Field Standard Operating Procedures (SOPs) approved for previous work at the Asarco East Helena Site will be used as guidance for collection of field water quality parameters. Laboratory analytical methods are from EPA's Methods for Chemical Analysis of Water and Wastes (1983); or Standard Methods for the Examination of Water and Wastewater (SM). Equivalent procedures may be used as long as detection limits are achieved.

Table 13. Biota sample analytical parameter list.

Parameter	Analytical Method(1)	Soil Sample Project-Required Detection Limit (mg/kg)	Sediment Sample Project-Required Detection Limit (mg/kg)
Aluminum (Al)	SW 3050/6010B/6020	100	100
Antimony (Sb)	SW 3050/6010B/6020	0.1	0.5
Arsenic (As)	SW 3050/6010B/6020	0.1	1
Barium (Ba)	SW 3050/6010B/6020	100	100
Beryllium (Be)	*SW 3050/6010B/6020*	*10*	*10*
Cadmium (Cd)	SW 3050/6010B/6020	0.1	0.5
Chromium (Cr)	SW 3050/6010B/6020	5	5
Cobalt (Co)	SW 3050/6010B/6020	1	1
Copper (Cu)	SW 3050/6010B/6020	5	5
Iron (Fe)	SW 3050/6010B/6020	100	100
Lead (Pb)	SW 3050/6010B/6020	1	1
Manganese (Mn)	SW 3050/6010B/6020	10	10
Mercury (Hg)	SW 7471/6010B/6020	0.05	0.05
Nickel (Ni)	SW 3050/6010B/6020	5	5
Selenium (Se)	SW 3050/6010B/6020	0.5	0.5
Silver (Ag)	SW 3050/6010B/6020	2	0.1
Thallium (Tl)	SW 3050/6010B/6020	0.1	1
Vanadium (V)	SW 3050/6010B/6020	1	10
Zinc (Zn)	SW 3050/6010B/6020	5	10
Methyl Mercury (MeHg)	EPA Method 1630	0.02 ng/kg	0.02 ng/kg
Moisture Content	EPA Method 160.3	0.1%	0.1%

(1) Laboratory analytical methods are from EPA's Test Methods for Analysis of Solid Waste (SW-846). Equivalent procedures may be used as long as detection limits are achieved

June 26, 2009

Table 14. Flow-path analysis monitoring points

Flow Path 1						
Monitoring Points	Lower Lake	DH-4	PZ-1*	PZ-2*	IST-1*	PPC-5
Total Depth (fbgs)	NA	23	10	10	2-Jan	NA
Screen Length (ft)	NA	6	5	5	0.2	NA
Flow Path 2						
Monitoring Points	Lower Lake	APSD-7	PZ-4**	IST-2	PPC-103	
Total Depth (fbgs)	NA	16	10	2-Jan	NA	
Screen Length (ft)	NA	7.5	5	0.2	NA	
Flow Path 3						
Monitoring Points	Lower Lake	APSD-8	PZ-5	IST-3	PPC-102	
Total Depth (fbgs)	NA	15	10	2-Jan	NA	
Screen Length (ft)	NA	10	5	0.2	NA	

*Total depth and screen length are approximate and may be adjusted due to field conditions

Table 15. Exposure parameter profiles for wildlife receptors

	American Robin *Turdus migratorius* *Avian Omnivore*		Belted Kingfisher *Ceryle alcyon* *Avian Piscivore*		Mallard *Anas platyrhynchos* Avian Omnivore		Short-tailed Shrew *Blarina brevicauda* Mammalian Insectivore		Mink *Procyon lotor* Mammalian Omnivore		Tree Swallow *Tachycineta bicolor* Avian Insectivore	
	Value	Source	Value	Source	Value	Source	Value	Source	Value	Source	Value	Source
Body Weight (BW) (kilograms)	0.077	Clench and Leberman (1978, as cited by U.S. EPA 1993)	0.15	Brooks and Davis (1987, as cited by U.S. EPA 1993)	1.04	Nelson and Martin (1953, as cited in U.S. EPA 1993)	0.012	Guilday (1957, as cited by U.S. EPA 1993)	0.55	Silva and Downing (1995)	0.021	McCarty (1995)
Body Weight (BW) (grams)	77		150		1040		12		550		21	
Food Ingestion Rate (grams/day, dry weight)	*10.2*	*Estimated from* Nagy (2001) for omnivorous bird	*23.5*	*Estimated from* Nagy (2001) for carnivorous bird	*52.2*	*Estimated from* Nagy (2001) for omnivorous bird	*1.7*	*Estimated from* Nagy (2001) for insectivorous mammal	*29.5*	*Estimated from* Nagy (2001) for carnivorous mammal	*4.6*	*Estimated from* Nagy (2001) for insectivorous bird
BW-normalized Food Ingestion Rates (NFIRdry) (kg/kg bw-day, dry weight)	0.13		0.16		0.05		0.15		0.05		0.22	
BW-normalized Food Ingestion Rates (NFIRwet) (kg/kg bw-day, wet weight)	0.66	Estimated from $NFIR_{dry}$, using 80% moisture content	0.78	Estimated from $NFIR_{dry}$, using 80% moisture content	0.25	Estimated from $NFIR_{dry}$, using 80% moisture content	0.73	Estimated from $NFIR_{dry}$, using 80% moisture content	0.27	Estimated from $NFIR_{dry}$, using 80% moisture content	1.1	Estimated from $NFIR_{dry}$, using 80% moisture content
Fraction Soil/Sediment of Diet (FSD)	0.104	Beyer et al. (1994)	0.01	Beyer et al. (1994)	0.033	Beyer and Fries (2003)	0.094	Beyer et al. (1994)	0.094	Beyer et al. (1994)	0	Beyer et al. (1994)
Normalized Soil/Sediment Ingestion Rate (NSIR) (kg/kg bw-day, dry weight)	0.014	Calculated (product of $NFIR_{dry}$ and FSD)	0.002	Calculated (product of $NFIR_{dry}$ and FSD)	0.002	Calculated (product of $NFIR_{dry}$ and FSD)	0.014	Calculated (product of $NFIR_{dry}$ and FSD)	0.005	Calculated (product of $NFIR_{dry}$ and FSD)	0	
BW-normalized Water Ingestion Rate (NWIR) (L/kg bw-day)	0.14	Estimated from Calder and Braun (1983)	0.11	Estimated from Calder and Braun (1983)	0.06	Estimated from Calder and Braun (1983)	0.15	Estimated from Calder and Braun (1983)	0.11	Estimated from Calder and Braun (1983)	0.21	Estimated from Calder and Braun (1983)
Dietary Components	Earthworms, insects, vegetation (grass, berries, *seeds)*	U.S. EPA (1993)	Fish, crustaceans, insects, crayfish, amphibians, *mammals*	U.S. EPA (1993)	Seeds, grains, aquatic invertebrates	U.S. EPA (1993)	Earthworms, insects, misc. animals	U.S. EPA (1993)	Fish, frogs, invertebrates	U.S. EPA (1993)	Insects	U.S. EPA (1993)

Table 18. Avian and mammalian TRVs for ecological risk calculations

Constituent	Class	Test Species	Body Weight (kg)	Exposure Route	No-Effects Dose Concentration	Lowest-Observed-Effects Dose Concentration	Ingestion Rate	Endpoint	Duration of Study	Uncertainty Factor	NOAEL (mg/kg-d)	LOAEL (mg/kg-d)	Reference
Aluminum	Birds	Ringed dove	0.155 [a]	oral in diet	1,000 ppm	–	0.0173 kg dw/day[b]	reproduction	4 months	—	124	—	Carriere et al. (1986)
	Mammals	Mouse	0.03 [c]	oral in water	–	19.3 mg/kg bw-day	–	reproduction	3 generations	0.1 [d]	1.93	19.3	Ondreicka et al. (1966)
Antimony	Mammals	Rat	0.33	oral in water	1 mg/L; 53.83% Sb by MW	10 mg/L; 53.83% Sb by	0.13 L/kg/day	reproduction	31 days during gestation	—	0.07	0.72	Rossi et al. (1987)
Arsenic as Arsenate	Birds	Mallard duck	1.0 [h]	oral in diet	100 ppm	400 ppm	0.100 kg/day[h]	reproduction	4 weeks	—	10	40	Stanley et al. (1994)
	Mammals	Rabbit	–	oral in food	–	–	–	reproduction	18 days during gestation	—	0.75	3	Nemec et al. (1998)
Barium	Birds	Chicks	0.121 [l]	oral in food	2,000 ppm	4,000 ppm	0.0126 kg/day[m]	mortality	4 weeks	0.1 [e]	21	42	Johnson et al. (1960)
	Mammals	Mouse	0.307	oral in water	61 mg/kg/day	121 mg/kg/day	–	growth	92 days	0.1 [e]	6.1	12	Dietz et al. (1992)
Beryllium	Mammals	Rat	0.35 [c]	oral in water	5 mg/L	–	0.046 L/day[j]	growth	lifespan	—	0.66	—	Schroeder and Mitchener (1975)
Cadmium	Birds	Mallard duck	1.153	oral in diet	15.2 ppm	210 ppm	0.110 kg/day	reproduction	90 days	—	1.45	20	White and Finley (1978)
	Mammals	Rat	0.303	oral gavage	1 mg/kg bw-day	10 mg/kg bw-day	–	reproduction	6 weeks through gestation	—	1.0	10	Sutou et al. (1980)
Chromium	Birds	Black duck	1.25	oral in diet	10 ppm	50 ppm	0.0785 kg/kg-day[k]	reproduction	10 months	—	0.86	4.32	Haseltine et al. (1985)
	Mammals	Mouse	0.0249	oral in food	–	100 ppm; 38.02% Cr3+	0.16 kg/kg/day	reproduction	35 days	0.1 [b]	0.596	5.96	Zahid et al. (1990)
Cobalt	Birds	Peking duck	0.5	oral in food	0.02% of diet	0.2% of diet	0.21 kg/kg/day	growth	8 days	0.1 [e]	4.1	41	Paulov (1971)
	Mammals	Rat	–	oral in diet	5 mg/kg bw-day	20mg/kg bw-day	–	neurological tests, testicular atrophy	69 days	0.1 [e]	0.50	2.0	Nation et al. (1983)
Copper	Birds	Mallard duck	–	oral in food	218.5 ppm	420 ppm	0.26 kg/kg/day	growth	35 days	—	5.68	10.9	Foster (1999)
	Mammals	Mink	1.0 [m]	oral in diet	25 ppm and 60.5 ppm in food	50 ppm and 60.5 ppm in food	0.137 kg/kg bw/day	kit mortality	357 days	—	12	15	Aulerich et al. (1982)
Lead	Birds	American kestrels	0.13	oral in diet	50 ppm	–	0.01 kg/day[p]	reproduction	7 months	—	3.85	—	Pattee (1984)
	Birds	Japanese quail	0.15 [q]	oral in food	–	100 ppm	0.169 kg dw/kg/day	reproduction	12 weeks	—	—	11	Edens et al. (1976)
	Mammals	Rat	0.35 [c]	oral in diet	141 ppm	1130 ppm	0.028 kg/day[g]	weight of weanlings and growth	3 generations	—	11	90	Azar et al. (1973)
Manganese	Birds	Turkey	0.45	oral in food	4080 ppm	4800 ppm	0.06 kg/kg/day	growth	21 days	0.1 [e]	26	30	Vohra and Kratzer (1968)
	Mammals	Rat	0.35 [e]	oral in diet	1,050 ppm and 50 ppm in food	3,500 ppm and 50 ppm in food	0.028 kg/day[g]	reproduction	224 days	—	88	280	Laskey et al. (1982)
Mercury	Birds	Japanese quail	0.15 [q]	oral in diet	4.4 ppm dw	8.8 ppm dw	0.168 mg/kg-day[k]	reproduction	1 year	—	0.74	1.5	Hill and Shaffner (1976)
	Mammals	Mink	1.0 [m]	oral in diet	7.39 ppm	–	0.137 kg/day[n]	reproduction	6 months over gestation	—	1.0	—	Aulerich et al. (1974)
	Mammals	Mouse	0.03 [c]	oral in water	–	75 ppm	0.0075 L/day[j]	body mass, kidney function	7 weeks	—	—	18.8	Dieter et al. (1983)

Table 16. (cont.)

Constituent	Class	Test Species	Body Weight	Exposure Route	No-Effects Dose Concentration	Lowest Observed Effects Dose Concentration	Ingestion Rate	Endpoint	Duration of Study	Uncertainty Factor	NOAEL	LOAEL	References
Methyl Mercury	Birds	Mallard	1.0	oral in diet	—	0.5 ppm	0.128 kg/kg/day	duckling survival	3 generations	0.5	0.032	0.5	Heinz (1974, 1976a,b, 1979)
	Mammals		*0.35*	*oral in diet*	*0.5 ppm*	*2.5 ppm*	*0.028 kg/day*[c]	*reproduction*	*3 generations*	—	*0.032*	*0.16*	Vershuuren et al. (1976)
Nickel	Birds	Mallard ducklings	0.782	oral in food	176 ppm	774 ppm	0.17 kg/kg/day	mortality	90 days	—	31	135	Cain and Pafford (1981)
	Mammals	Rat	0.35 [c]	oral in diet	500 ppm	1,000 ppm	0.028 kg/day[g]	offspring body weight	3 generations	—	40	80	Ambrose et al. (1976)
Selenium	Birds	Mallard duck	1.043	oral in diet	3.5 ppm dry wt	7 ppm dry wt.	0.05 kg dw/kg/day	reproduction	122 days	—	0.2	0.4	Stanley et al. (1996)
	Mammals	Rat	0.35 [c]	oral in water	1.5 mg/L	2.5 mg/L	0.046 L/day[f]	reproduction	2 generations	—	0.20	0.33	Rosenfeld and Beath (1954)
Silver	Birds	Turkey	0.411	oral in food	300 ppm	900 ppm	0.23 kg/kg/day	growth	4 weeks	0.1 [e]	6.8	21	Jensen et al. (1974)
	Mammals	Rat	0.2	oral in food	–	50 mg/organism/day; 75.2% Ag by MW	–	reproduction	20 days during gestation	0.1 [d]	18.8	188	Shavlovski et al. (1995)
Thallium	Birds	Ring-necked pheasant	–	acute oral gavage	–	23.7 mg/kg bw	–	mortality	–	0.01, [d] 0.1	0.237	23.7	Hudson et al. (1984)
	Mammals	Rat	0.365	oral in water	–	270 ug/rat/day	–	reproduction	60 days	0.1 [d]	0.074	0.74	Formigli et al. (1986)
Vanadium	Birds	Mallard duck	1.17	oral in diet	110 ppm	–	0.121 kg/day	mortality, body weight, blood	12 weeks	—	11	—	White and Dieter (1978)
	Mammals	Rat	0.26	oral intubation	–	2.09 mg/kg-day	–	reproduction	>60 days, through	0.1 [d]	0.209	2.09	Domingo et al. (1986)
Zinc	Birds	White leghorn hen	1.766	oral in diet	2,000 ppm	–	0.114 g/day	reproduction	44 weeks	—	130	—	Stahl et al. (1990)
	Mammals	Sprague-Dawley rat	0.35 [c]	oral in diet	2,000 ppm	4,000 ppm	0.028 kg/day[g]	reproduction	16 days during gestation	—	160	320	Schlicker and Cox (1968)

Table 16. (cont.)

Note: Dose concentrations and ingestion rates are expressed in wet weight unless otherwise noted.

BEHP	-	bis(2-ethylhexyl)phthalate	PAH	-	polycyclic aromatic hydrocarbon
bw	-	body weight	PCB	-	polychlorinated biphenyl
CoPC	-	chemical of potential concern	RCRA	-	Resource Conservation and Recovery Act
DEHP	-	diethylhexyl phthalate	TRV	-	toxicity reference value
dw	-	dry weight	UF	-	uncertainty factor
LOAEL	-	lowest-observed-adverse-effect level	ww	-	wet weight
NOAEL	-	no-observed-adverse-effect level			

[a] Terres (1980).

[b] Nagy (1987).

[c] U.S. EPA (1988).

[d] LOAEL to NOAEL UF.

[e] U.S. EPA (1995).

[f] Calder and Braun (1983).

[g] Calculated using allometric equation from U.S. EPA (1988).

[h] Heinz et al. (1989).

[i] U.S. EPA (1988), mean at 14 days.

[k] Based on an reasonable maximum exposure of 430 kcal/kg-day derived from Nagy (1987), an assimilation efficiency of 80 percent, and an energy content of 3,190 kcal/kg dry weight.

[l] U.S. EPA (1988), mean at 5 weeks.

[m] U.S. EPA (1993).

[n] Based on the observations of Bleavins and Aulerich (1981).

[o] Sample et al. (1996).

[p] Shellenberger (1978), for 3-week old male quail.

[q] Vos et al. 1971.

[r] LOAEL to NOAEL UF, recommended by U.S. EPA (1995).

[s] Subchronic to chronic UF.

Table 17. Oral TRVs for fish (from U.S. EPA 2005b)

Metal	Threshold TRV	NOAEL TRV	LOAEL TRV
Arsenic	40	63	137
Cadmium	—	55	165
Copper	—	340	660
Lead	—	170	510
Zinc	—	1500	4500

Note: These values are reproduced from the Supplemental ERA (U.S. EPA 2005b) and were derived from the Clark Fork River, Montana, ERA

TRV: Toxicity reference value (in mg/kg, dry weight)
NOAEL: No observed adverse effect level
LOAEL: Low observed adverse effect level

Appendix A

Field Sampling and Analysis Plan (FSAP)

Appendix B

Application for Scientific Collector's Permit

Montana Fish, Wildlife & Parks

APPLICATION FOR SCIENTIFIC COLLECTOR'S PERMIT
FISHERIES

Date: May 15, 2009

1. Name, phone number, affiliation, qualifications of the applicant and associates who will be conducting collection of fish. (Please attach additional sheets if necessary.)

Applicant's Name:	Linda Ziccardi
Address:	4141 Arapahoe Ave, Suite 101, Boulder, CO 80303
Phone#:	303 619-5171, 303 697-8555
Affiliation:	Exponent
Email Address:	lziccardi@exponent.com
Qualifications:	20+ years experience eco risk assessment, field studies, BS Natural Resource Management & Applied Ecology
Associate's Name:	Ken Cerreto, Ben Amos
Address:	3 Clocktower Place, Suite 205, Maynard, MA 01754
Phone#:	508 314-1156
Email Address:	kcerreto@exponent.com, bamos@exponent.com
Affiliation:	Exponent
Qualifications:	Ken Cerreto: 10+ years experience eco risk assessment, stream ecology, fisheries, MS in Zoology & Physiology, BA in Biology Ben Amos: 7 years experience in eco risk assessment, specializing in the sampling of sediment, surface water, and aquatic biota

FWP receives requests for mailing lists. Do you want your name included on lists provided by FWP to requestors? Yes ______ No X

2. Description of supervision provided by the applicant to associates. For example, will the applicant be in the field on a daily basis or will supervision be remote?

   Applicant and associates will be in the field on a daily basis conducting sampling as a team.

3. Description of why the collection is necessary (i.e., why collection by angling within creel limits by anglers is not possible):

   Collection is necessary to determine metals body burdens in fish, aquatic invertebrates, terrestrial invertebrates, amphibians, and aquatic plants. Data will be utilized in a human health and ecological risk assessment being conducted under RCRA for the Asarco East Helena Smelter site located in East Helena, in Lewis and Clark County. Asarco is cooperating with U.S. EPA and U.S. Fish and Wildlife Service in the conduct of the risk assessment activities.

4. Description of study plan (please attach research proposal if available):

   Field study will include collection and chemical analyses of earthworms, benthic and soil invertebrates, fish, amphibians; other wildlife prey items including mussels, snails, and crayfish; and aquatic plants and algae. Biota sample station locations will coincide with stations for sampling of surface water, sediment, and soil. Water bodies that will be sampled include Prickly Pear Creek, and Lower and Upper Lakes and the associated marsh. Samples will also be collected from appropriate reference locations that will be selected in the field. Montana Fish, Wildlife & Parks will be notified of the location of the reference sites after appropriate sites are selected. A detailed work plan/field sampling and analysis plan are being developed for this work. Exponent can provide Montana Fish, Wildlife & Parks with a copy of the work plan/field sampling plan prior to the conduct of this work. The field work is planned for late July/early August 2009.

5. Description of collection gear and method(s) of collection. If electrofishing is to be utilized, describe equipment and type of electrical current used. Include description of personnel experience and training with electrofishing if appropriate.

   The collection gear and methods will include:

   - Aquatic invertebrates: dip net, benthic sampler (e.g. Surber net), traps (e.g, crayfish traps)
   - Amphibians: dip nets, hand collection, baited traps
   - Fish: beach seine, dip net, baited traps, gill net, backpack electroshocker (Smith-Root model 12-B POW, 100-1000 volt range in a 60-amp peak output current), possibly rod and reel
   - Aquatic macrophytes and algae: hand collection, dip net
   - Terrestrial invertebrates (earthworms and insects): digging, pitfall traps, hand collection

   Field team members have appropriate training and experience using the backpack electroshocker, including having taken a standard electrofishing and water safety course. Field team members will be provided appropriate safety gear including footwear, waders, and gloves. The appropriate Montana fishing licenses will be obtained. Field team members also have experience using other sampling equipment including dip nets, traps, seines, and gill nets. Standard operating procedures that detail the methods of sample collection will be included as part of the field sampling plan. Montana Fish, Wildlife & Parks electrofishing and gill netting guidelines will be followed.

6. Describe the collection locations, dates, anticipated number of fish to be collected and the anticipated number to be kept.

Actual fish species that will be collected will be determined in the field, based on abundance. Species expected to occur in Prickly Pear Creek include brook trout, brown trout, longnose sucker, mottled sculpin, rainbow trout, walleye, white sucker, and longnose dace. Fish species expected in Upper Lake include brook trout, brown trout, common carp, fathead minnow, largemouth bass, longnose dace, longnose sucker, mottled sculpin, mountain whitefish, rainbow trout, smallmouth bass, stonecat, walleye, white sucker, and yellow perch.

The risk assessment requires collection of forage and predatory fish, common amphibians, benthic invertebrates, aquatic macrophytes and algae, earthworms and terrestrial insects for wildlife food chain modeling. Lab requirements will dictate the number of individual organisms that will be collected to create composite samples of sufficient mass for chemical analysis. Fish and invertebrates will be collected from Prickly Pear Creek, Upper Lake and Lower Lake (if fish are present). Upper and Lower Lakes are on the Asarco plant property. Prickly Pear Creek, which runs along the plant's eastern boundary, is a tributary to the Missouri River, within the Central Fishing District. Tables 1 and 2, attached provide information on the sampling locations and proposed sample numbers.

6. Describe the proposed disposition of those specimens collected and kept:

Will live fish be transported from the capture location? Yes* ________ No __X__

Individual fish and other biota will be collected and composited to meet the mass requirements of the analytical laboratory. Samples will be stored on ice, in coolers, and shipped to the analytical laboratory for analyses.

8. Describe provisions that will be made to protect Threatened and Endangered Species and Montana Species of Special Concern (see attached).

Threatened and Endangered Species and Montana Species of Special Concern are not expected to occur in Prickly Pear Creek or onsite in Upper and Lower Lakes. If any listed species are observed or captured, they will be noted in the field log book and released. Field team members will be trained in recognizing Montana Species of Special Concern.

9. Attach study plans if available.

A detailed work plan/field sampling and analysis plan are under development and will be provided to Montana Fish, Wildlife & Parks at their request prior to the conduct of this work.